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ABSTRACT

Described is the Deaf Blind Communications System (DEBLICOM), a somesensory coded information transfer system in which information is received cutaneously and transmitted kinesthetically. Reported is a pilot study done with 15 normal Ss (13- to 21-years-old) which compared communicative effectiveness of conventional temporal Morse code, spatial temporal Morse code and the dual input DEBLICOM code. Two styles of DEBLICOM interfaces are discussed: a touch-feel, portable, finger interface with nothing worn on or attached to the body of the deaf blind person and a body receive-only interface. Also explained are parts, materials and engineering aspects of the DEBLICOM system. (GW)

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MID-TERM PROGRESS REPORT

# DEBLICOM

## DEAF-BLIND COMMUNICATION & CONTROL SYSTEMS

GRANT NO. 23-P-57488/3-05

For Period Covering Sept. 1, 1976 — Feb. 28, 1977

Submitted to

REHABILITATION SERVICES ADMINISTRATION
OFFICE OF HUMAN DEVELOPMENT
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

By

CYBERNETICS RESEARCH INSTITUTE
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ABSTRACT

DEBLICOM (DEaf-BLInd COMmunications System) is a somesensory coded information transfer system which embodies a common dual code for reception and expression. The system is designed for the cutaneous reception of information and kinesthetic transmission of information. It is principally for use by people who have the sensory systems of their eyes and ears totally precluded or critically limited from accepting and delivering to the cognitive centers of the brain external visual and auditory uncoded or coded stimuli irrespective of its waveform, intensity, duration, frequency or bandwith.

The purpose of DEBLICOM is to provide two-way cutaneous-kinesthetic communication means for persons who are deaf-blind and who may be speech-impaired. It is designed to serve teachers and specialists who wish to supplement presently used inadequate methods with a system that is both simple to learn and has potential for an even broader spectrum of social communication. By these means people may utilize a variety of computer systems keyboards as educational, rehabilitational, and vocational tools even though they are deaf-blind.

The concept upon which DEBLICOM is based embodies a person's somesthetic capabilities to kinesthetically transmit coded information by means of their fingers and to cutaneously receive information through coded touch or palpable vibratory

stimuli. It makes use of a common dual-code arrangement in the receptive or expressive modes simultaneously or sequentially. In one arrangement of the system a "transmit"/"receive" (T/R) finger-operated interface is used, with no harness or other attachment to the user's body.

The first two-way cutaneous-kinesthetic communication device used by a person who is deaf-blind using a dual code common to both "receive" and "transmit" modes was demonstrated by Mr. Earl Brawner, of the U.S. Library of Congress. He was taught to use a finger-operable "Cybertac"* interface at the C/R/I laboratories.**

## INTERFACE CONFIGURATIONS

The T/R interface may be configured to serve two purposes; one as a "keyboard" in which two keys are struck to transmit information, and the other as a "keyboard" to receive information. In the "receive" mode, dual combinations of the keys or transducers adjacent to or built into the keys vibrate in accordance with a prescribed code. All fingers rest on the interface and vibrations are felt at assigned finger locations in accordance with a predetermined dual-loci code in which the locations are identical to the dual-keying transmit code. In either "transmit" or "receive" modes, a pair

*See C/R/I Second Report, *Study of Man-Machine Communications Systems for the Handicapped*, sec. I.II: "Cybertac," p.17 (Aug. 19, 1968), ERIC No. ED 025 890

**Project Research Grant Number 23-P-57488/3-05 supported by the Rehabilitation Services Administration (RSA), Office of Human Development, Department of Health, Education, and Welfare

of keys represent a coded element. These elements may be designated as individual alphanumeric characters, machine functions, words, phrases, or longer specific messages. With deaf-blind persons who have loss of fingers or have only one hand a single dual sequential limb interface may be used.

## DEBLICOM FEATURES

Features of the DEBLICOM Information Transfer System (DITS) include:

1. Compatibility with a common input/output (I/O) keyboard or transmit/receive (T/R) interface for the operation of portable DITS communicators or remote computer terminals (e.g., TTYs).
2. DEBLICOM can be used for face-to-face communications in the event of equipment unavailability, through use of hand-to-hand DEBLICOM-coded signing.
3. The inputs of DITS can be keyed or programmed from standard typewriter keyboards; communication boards such as "pointing," "touch," "message," or of the "writing tablet" type.
4. The DEBLICOM systems may be used by nondisabled individuals having little or no experience with special codes or keyboards. This enables nondisabled individuals to communicate directly, either face-to-face or indirectly by telephone with people who are

deaf-blind and who may or may not be speech-impaired.

5. Low cost.

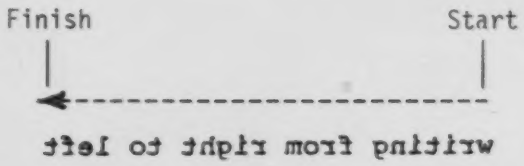
## LEARNING PROBLEMS

The teaching of any method for transmitting and receiving information to persons who are deaf-blind has presented severe problems to teachers and specialists in this area. Moreover, people who are deaf-blind are confronted with perplexing problems; the cutaneous-kinesthetic punctographic language—as it is read tactually or written punctographically—is filled with inherent complexities and ambiguities. There are major problems associated with teaching and learning Braille, since this code is intrinsically ambiguous with patterns having limited coding capacity* and multiple meanings according to the level or grade of the coding. With only six dot positions in each cell, Braille yields 63 combinations, 31 of which are identical stand-alone configurations. Thus, Braille's use relies on the reader's skill and ability to read in context or with a frame of reference to adjacent patterns. All 63 patterns have at least three different assigned meanings and some of them have even four.

Further, to write Braille using a slate and stylus, one must learn to write the characters backwards, starting

*See C/R/I Interim Report, *Study of Man-Machine Communications Systems for the Handicapped* (Aug. 19, 1968), ERIC No. ED 025 890

from right to left, as indicated here by the following mirror-image:




(when reversed this illustration reads "writing from right to left"). Each matrix (recessed mold) of the character's configuration is reversed laterally. When the writing material is removed from the slate and turned over, each patrix (protruding point) of the character's configuration is tactually detected by the finger. The direction of tactual reading of horizontally sequential Braille patterns is left to right, as are the words on this page. By contrast, HAIBRL®,* a punctographic language whose patterns are all unequivocal, is rich in character capacity, contains a built-in referent, and may be written and read straightforward.

Braille is used by fewer than 50,000 persons in the United States out of a population of about 400,000 persons in the United States who are legally blind. Today there are about 350,000 legally blind people in this country who are not deaf. Yet, they cannot read or write Braille. This drawback plus its complexity and ambiguity does not make it a likely candidate for use by the great majority of persons who are deaf-blind.

*Kafafian (1968), U.S. Pat. No. 3,718,991, "Tactually Interpretable Cell and Slate for Forming the Same." See C/R/I Final Report (Vol. III, 1971), *Study of Man-Machine Communications Systems for the Handicapped*, Part Seven: "HAIBRL," p. 101.

For social purposes, "finger spelling" on the palm or other parts of the body such as the shoulder or upper back areas is designed for communications with and by persons who are deaf-blind. Sign languages have also been developed for communication with and by motivated persons with good cognitive capabilities, but their use is again limited to families, friends, and colleagues. Only some specialists and a few others with normal constitutions learn and use these methods proficiently because of social links, rehabilitational or job requirements. But for the most part few people ever communicate with individuals who are deaf-blind unless it is directly through an interpreter or with the assistance of special educators, counsellors, or specialists at a school or institute engaged with clients who may have lost or may be losing sight and/or hearing capabilties.

The needs for more effective communicatory aids and easily learned, unambiguous codes are critical. These together with reliable, low-cost, portable systems for use in social, educational, rehabilitative, and vocational endeavors by persons who are deaf-blind and who may be speech-impaired , are the objectives towards which the DEBLICOM concept is directed.

Therefore, one of the purposes of this research program is to provide an economically and easily learned two-way communication system for use by this segment of the disabled

population. These concepts and approaches are applicable to present and future generation living in a computer-oriented society who are or may become deaf-blind and/or speech-impaired because of heredity, disease, genetic mutation, accident, explosion, radiation, also therapeutic, medical or surgical misadventure, or natural causes.

The DEBLICOM systems will not preclude individuals who are deaf-blind and who have learned the code from using communication systems that we, with normal constitutions have access to; i.e., telephones, TTYs, computer terminals, such innovative and promising information transfer systems as the EIES* computer conferencing systems under study by the National Science Foundation at educational, governmental, and research centers in the United States.

Moreover, as an outgrowth of our continuing social conscience, researchers may perceive and implement even more beneficial cybernetic systems for persons who are severely disabled, in critical need of communicatory and other aids. With focused attention on a better understanding of needs, development of new materials, microprocessing technology, and other innovations designed for the special needs of this segment of the disabled population, systems such as DEBLCIOM may more quickly enter the marketplace and be effectively utilized.

*Turoff, M. and H. Gage, "Computerized Conferencing and the Homebound Handicapped" (Research Report No. 6), New Jersey Institute of Technology (May 24, 1976); Turoff, M. and S. Hiltz, "Computer-Mediated Communications and the Disadvantaged," New Jersey Institute of Technology (1976)

# DEBLICOM

## A CUTANEOUS-KINESTHETIC TWO-WAY COMMUNICATIONS SYSTEM FOR PERSONS WHO ARE DEAF-BLIND AND WHO MAY BE SPEECH-IMPAIRED

### INTRODUCTION

DEBLICOM is an information transfer system for use in two-way communications with and by persons who are deaf-blind. It may serve as an alternative means to enhance two-way communications capabilities in secure, hostile, or high-density-information environments.

The sensitivity, accuracy, reproducibility, stability, and reliability of the body's somesthetic systems to stimuli—and the living system's cutaneous-kinesthetic adaptability in transferring coded information to or from the brain over a wide range of choices of perceptions and sensations introduced to the central nervous system—together with an innate ability of the mind to will and control cutaneous-kinesthetic behavior in a prescribed manner, are truly cybernetic wonders of the living animal.

The use of a person's propreoceptive capabilities for communication purposes has been demonstrated by persons who are deaf-blind and who may be speech-impaired. Their ability to learn cutaneous-kinesthetic codes exemplifies these innate human properties. But serious coding constraints with present communications methods preclude or limit persons who are deaf-blind to a select or small group of individuals with whom they

can establish dialogue. Moreover, most individuals who are deaf-blind are restricted in the full development and extension of their cognitive and creative abilities But through the better understanding of the neuroanatomy of the human integument, new cybernetic systems—based on advancements in science, technology, and cutaneous research—promise to yield more effective and socially acceptable two-way communications systems.

In earlier stages of cutaneous communication, research efforts centered around approaches in which information reception was presented through the application of complex, variable, and dynamic patterns of stimuli applied to the integument of a person's body. No satisfactory discrimination of these patterns occurred. (Katz, 1930; Gault, 1936; Wiesner, 1949). There, the transmission rate of information to persons receiving the cutaneous stimuli was low and the ambiguities were high. Many of the problems were associated with the inability to discern and explicitly identify a plurality of patterns which simultaneously appeared as palpable vibrations. The ambiguities of these palpable vibrations also limited or precluded unequivocal interpretations. These difficulties can be attributed to a variety of indiscriminate changes in the waveform, frequency, intensity, attack rate of the stimuli, along with the complications of the subject being rapidly presented with a multiplicity of varied stimuli at the very same and/or different body locations. The difficulties become even more compounded with

varying levels of a subject's cognitive awareness and responsive capabilities.

Geldard (1954) reviewed those elements of cutaneous vibratory stimuli of the first order identifiable as location, intensity, duration, and frequency. Spector (1954) provided data on vibratory intensity and reported that the limits of absolute threshold for this area was about 20 microns and a level of approximately 0.5cm. Spector and Howell (1957) subsequently provided valuable insight into the significance of locus.

In 1956, Howell introduced the "Vibratese," a receiving device in which a 45-element multidimensional code employed the three elements identified by Geldard. An analysis of the obtained data reveals that the majority of errors resulted from misidentification of various levels of intensities. The coding of stimuli elements used with the device were not applicable to a common or one-to-one finger transmitting and receiving scheme.

Skin sensitivity to vibratory stimuli increases markedly with higher vibration rates until the frequencies reach the range of maximum sensitivity between 150-500Hz, above which it declines (IEEE, 1970). In 1965, Sherrick introduced a rugged, low-cost electromechanical vibration transducer, the first practical transducer for cutaneous communication applications.

In 1966, Foulke and Stricht investigated a tridimensional electrocutaneous communication code in which various coded

patterns were introduced to a person's body through means of temporal sequential stimuli on one part of the body. Foulke suggested that complexities in stimuli-demands create additional encoding processes in cognition, thereby increasing the reaction time for stimuli identification.

In 1968, Foulke and Brodbeck further explored electrocutaneous stimulation using the temporal sequential telegraph code invented by Morse (1832). They concluded that it would be feasible to utilize a cutaneous Morse code, provided that adequate training was established, while optimizing the parameters affecting the perception of cutaneous signals.

A conversion of Morse's temporal telegraphic code to include separate cutaneous channels was proposed in 1976 by Kafafian,* and the following question was raised: "Has anyone considered the use of two separate and appropriate sites of the body if they were sequentially stimulated cutaneously, with one location for the 'dash' element and the other location for the 'dot' element in which dot elements had identical durations?"* (See the following section in the Pilot Study, "Cutaneous Communications Codes, Etc.," at page 29).

Towner and Diespecker (1973), in their evaluation of a coded vibrotactile language which included intensity, duration, and location parameters, showed that intensity and duration parameters were responsible for more stimuli identification errors than the loci parameter. In 1974, Sherrick suggested a learning method through use of games in which

*Private communications: Foulke, Sherrick, Kafafian

goal-directed behavior could be enhanced through cutaneous transfer of information. He proposed a unique recreational approach in which each outcome of a family of games could be gauged by the acquisition rate of information derived solely through cutaneous means.

"Cybertac,"* a dual-input/output vibrotactile code (Kafafian), was proposed in 1968 for two-way communications purposes in which bilateral locations on the fingers and thumbs were used to receive or transmit a simple, unambiguous, cutaneous-kinesthetic code. This permitted use of the hands for information transfer in both the receptive and expressive modes. Two sites, activated simultaneously, were used for each character or element of the code. The dual cutaneous coding followed the 14-key CYBERTYPE® bilateral coding scheme. With this coding arrangement,** information exchange can be achieved through use of a common transmit/receive (T/R) keyboard or interface without use of a body harness or vibrotactile transducers worn on the body of the user.

One embodiment of "Cybertac" was demonstrated for transmitting and receiving information cutaneously with the hands without use of vibrotactile transducers on the shoulders, trunk, or lower limbs of the body. This can be accomplished with use of both hands; or, for one-hand operation, use is made of the

*See C/R/I Interim Report, *Study of Man-Machine Communications Systems for the Handicapped*, sec. I.II: "Cybertac," p. 17 (Aug. 19, 1968), ERIC No. ED 025 890

**See C/R/I Second Report (Vols. I & II combined), *Study of Man-Machine Communications Systems for the Handicapped* (Feb. 19, 1970); see also companion C/R/I Final Report (Vol. III, 1971)

sequential dual-coding arrangement as employed in the CYBERTYPE 7-key, one-handed interface. We have taught one subject who is deaf-blind and many severely disabled students the dual-input CYBERCOM code. All have easily learned assigned functions,* such as letters, punctuation marks, and typewriter control functions, without difficulty.

Characters and other assigned functions are received in the form of dual-coded haptic stimuli on two fingers, one on each hand. The positions of the two vibrotactile stimulators for receiving information are essentially in the same positions as are the two keys or transducers used for transmitting the same character or other assigned function (see Figures 1 and 2).

The utility of this dual-coding method can be extended to computer conferencing applications for use by students who are deaf-blind and homebound. Essentially, these applications center around new computer conferencing techniques for the handicapped and disadvantaged (Turoff, Hiltz, Gage, 1976).** Use has been made of a wide range of interfaces designed to serve individuals who are severely physically and/or neurologically disabled and cannot write or use ordinary keyboards (Kafafian, 1969, 1971, 1973). It should be pointed out that one of the features of homebound computer conferencing is

*A function in the receive mode consists of a discrete contralateral pair of simultaneously selected palpable stimuli or discrete sequential pairs of dual-coded palpable stimuli to which meanings or elements of a language have been assigned.

**Turoff, M. and H. Gage, "Computerized Conferencing and the Homebound Handicapped" (Research Report No. 6), New Jersey Institute of Technology (May 24, 1976); Turoff, M. and S. Hiltz, "Computer-Mediated Communications and the Disadvantaged," New Jersey Institute of Technology (1976)

that the recipient of information need not be aware of the identity of the sender unless the sender chooses to be identified. Moreover, neither the rate at which the message is entered nor the sender's physical characteristics need be known by the recipient. Likewise, a person can retain anonymity irrespective of their sensory dysfunctions.

Cutaneous conferencing through use of computers opens an exciting new world for people with healthy minds who are deaf-blind and may be speech-impaired. It should be taught at the very first stages of deafness-blindness, or at an early stage to individuals who have loss of vision and are in the process of losing their hearing, or who have loss of hearing and are in the process of going blind. It is explicitly an innate property of the healthy human mind to create, associate, and make choices through self-generated internal stimuli within the labyrinth of the mind or through external stimuli introduced through one or more of the sensory channels. These innate properties together with the fact that humans can learn to use vibrotactile-kinesthetic languages clearly represent justification for consideration of a computer-compatible system for this segment of our severely disabled population. Cutaneous conferencing computer systems would also open new doors to individuals who are presently deaf-blind by extending their knowledge and self-realization through discovery of new worlds.

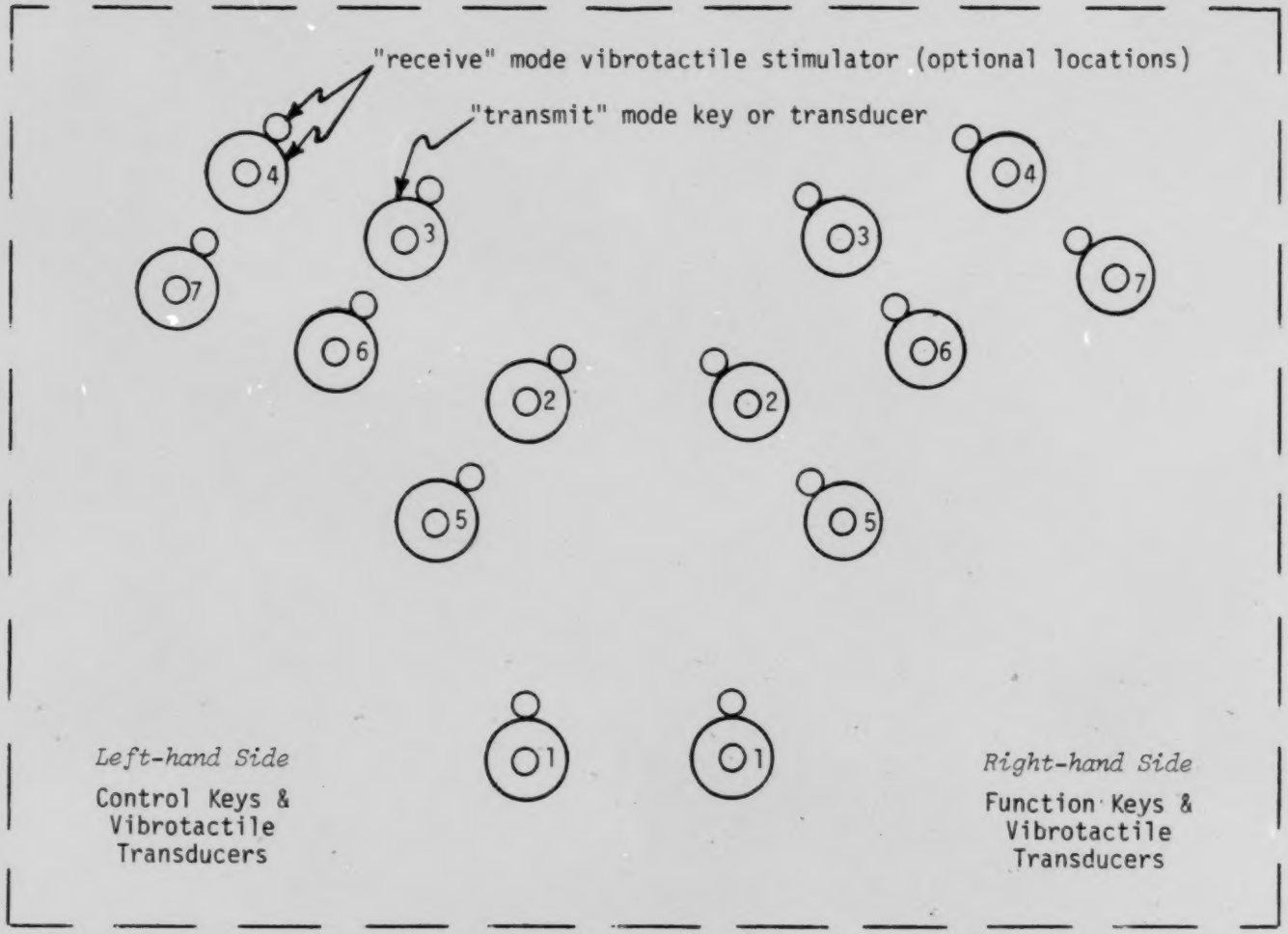



Figure 1. 14-key DEBLICOM Bilateral Transmit Receive Interface

# DEBLICOM CYBERCOM Dual-Input Code

## LETTER-KEYING CODE FOR 14-KEY DEBLICOM INTERFACE

| *Control Key* | *Function Key* | Interface Functions: *Upper Case* | Interface Functions: *Lower Case* | *Dual T/R* Code* |
|---|---|---|---|---|
| 1 | 1 | Space | | 1,1 |
| 1 | 2 | E | e | 1,2 |
| 1 | 3 | T | t | 1,3 |
| 1 | 4 | A | a | 1,4 |
| 1 | 5 | O | o | 1,5 |
| 1 | 6 | N | n | 1,6 |
| 1 | 7 | I | i | 1,7 |
| 2 | 1 | R | r | 2,1 |
| 2 | 2 | S | s | 2,2 |
| 2 | 3 | H | h | 2,3 |
| 2 | 4 | D | d | 2,4 |
| 2 | 5 | C | c | 2,5 |
| 2 | 6 | L | l | 2,6 |
| 2 | 7 | M | m | 2,7 |
| 3 | 1 | U | u | 3,1 |
| 3 | 2 | F | f | 3,2 |
| 3 | 3 | P | p | 3,3 |
| 3 | 4 | Y | y | 3,4 |
| 3 | 5 | B | b | 3,5 |
| 3 | 6 | G | g | 3,6 |
| 3 | 7 | W | w | 3,7 |
| 4 | 1 | V | v | 4,1 |
| 4 | 2 | J | j | 4,2 |
| 4 | 3 | K | k | 4,3 |
| 4 | 4 | . | Period . | 4,4 |
| 4 | 5 | Q | q | 4,5 |
| 4 | 6 | Z | z | 4,6 |
| 4 | 7 | X | x | 4,7 |

*Transmit/Receive

Figure 2. DEBLICOM CYBERCOM® Dual-input Code

| Control Key | Function Key | Interface Functions: Upper Case | Interface Functions: Lower Case | Dual T/R Code |
|---|---|---|---|---|
| 5 | 1 | Back Space | | 5,1 |
| 5 | 2 | _ | - | 5,2 |
| 5 | 3 | + | = | 5,3 |
| 5 | 4 | " | ' | 5,4 |
| 5 | 5 | , — Comma | , | 5,5 |
| 5 | 6 | ? | / | 5,6 |
| 5 | 7 | Tab | | 5,7 |
| 6 | 1 | Shift Unlock | | 6,1 |
| 6 | 2 | * | 8 | 6,2 |
| 6 | 3 | ( | 9 | 6,3 |
| 6 | 4 | ) | 0 | 6,4 |
| 6 | 5 | Colon : | Semicolon ; | 6,5 |
| 6 | 6 | Carriage Return | | 6,6 |
| 6 | 7 | Shift Lock | | 6,7 |
| 7 | 1 | ! | 1 | 7,1 |
| 7 | 2 | @ | 2 | 7,2 |
| 7 | 3 | # | 3 | 7,3 |
| 7 | 4 | $ | 4 | 7,4 |
| 7 | 5 | % | 5 | 7,5 |
| 7 | 6 | ¢ | 6 | 7,6 |
| 7 | 7 | & | 7 | 7,7 |

Figure 2. DEBLICOM CYBERCOM® Dual-input Code—*Continued*

# PILOT STUDY

This section constitutes the detailed description of the recent pilot study disclosed to representatives of RSA at the C/R/I laboratories. Its inclusion here should serve to provide continuity between prior progress reports and disclosures and the following current description of the DEBLICOM interface hardware and engineering activities.

## SUBJECTS

There were 15 subjects, having normal constitutions, who participated in the program. They were equally divided into Conditions I, II, and III and the differences in acquisition rates in learning the codes as achieved over all trials were measured. The subjects were students from two distinct communities. The first community provided nine high school students, 16-18 years of age, from Anne Arundel County, Maryland. They were paid $2.50 per hour as an incentive rate. The second community, from Washington, D.C., provided six subjects who answered an announcement in *The Washington Post*. Two of these subjects were paid for their services at the rate of $2.50 per hour. The other subjects ranged from 13-21 years. All of the subjects were told prior to the first session that they would be testing cutaneous codes. Separate groups of subjects were selected randomly for each of the three conditions on an equal basis. The subjects had no prior knowledge of either the conventional temporal Morse code, the spatial temporal Morse code, or the dual-input CYBERCOM code.

## TEST CODES

Three test codes were used in which the coded signals were cutaneously introduced: firstly, as vibrotactile stimuli on one finger of one hand; secondly, with similar vibrotactile stimulation introduced on two fingers, one from each hand; and thirdly, the dual-coding "Cybertac" scheme with only two cutaneous stimuli at selected sites of the fingers and thumbs.

The first code tested was the conventional Morse code in which the index finger of the dominant hand was used. The second code tested was the spatial Morse code in which the dots and dashes were assigned equal durations. Here the "dot" and "dash" elements were introduced palpably to the index fingers; the left index finger for the "dot" components and the right index finger for the "dash" components.

The third code was the CYBERCOM code; it consisted of contralateral pairs of simultaneously stimulated "touch" signals which were introduced to the fingers and thumbs of the hands placed on the face of the keyboard. (See the section: "Cutaneous Communications Codes, Etc.," page 29 of this report; see also Plate 4(b), page 19). The palpable stimuli appeared at two preassigned locations on the fingers and/or thumbs of the hands. Two stimuli, with one on one hand and the other on the other hand, represented a single element.

In earlier work (Kafafian, 1975),* an analysis of the transmission efficiency of these three codes revealed a 24 percent improvement in transmission time for the spatial Morse code and a 107 percent improvement in transmission rate for the

*C/R/I Second Quarterly Interim Progress Report, *DEBLICOM—Deaf-Blind Communication & Control Systems* (1976)

CYBERCOM code over the conventional Morse code. More recently, an in-depth analysis of the improvement achieved with the CYBERCOM code was made. (See the section, "Cutaneous Communications Codes, Etc.," at page 29 of this report).

Thus, a hypothesis was instituted: namely, that through improvements in the transmission efficiency of coded elements and an increase in cutaneous-kinesthetic channels, the use of dual-coding (e.g., CYBERCOM) would enhance the rate of transmission and the acquisition of information by the human controller over that of the Morse code. In addition, an increase in information transmission and acquisition rates was projected for temporal dual-channel (spatial) Morse code over the conventional temporal single-channel Morse code. (See Table I at page 36).

It may be pointed out here that, in addition to the standard CYBERCOM dual-coding assignments, complete messages can be prepresented by a single dual-coded cutaneous stimuli; for example, the assigned finger positions for the letter "S," which is represented by a single movement of both index fingers on or off the keyboard, could represent the message, "Please assist me by identifying these new surroundings." In a reverse manner, by touching the tips of both index fingers or by picking up the vibrations on both index fingers from the keyboard, a person can be informed that he or she will receive a description of the surroundings.

## METHOD

The stimulus manipulandum was a KIM-1 microprocessor (manufactured by MOS Technology) integrated with a CYBERCOM code interface component housing and selector mechanism (Plate 1). For a diagrammatic explanation of the hardware and software, see the section, "Engineering Description and Flowcharts," at page 39 of this report.

The CYBERCOM code dual-input stimuli were presented through the identical stimulator in which 16 solenoids were positioned in a bilateral array with eight stimulators on each side of a 14cm X 29.2cm X 7.6cm black plexiglass housing, as shown in Plate 2(b) adjacent to a standard 14-key CYBERTYPE interface (Plate 2(a)). The problems encountered in the tests were that the subjects had to make an effort to hold their hands on the flat surface of the interface.*

Both the conventional temporal Morse code and the spatial Morse code were introduced in the form of palpable stimuli to the surface of the fingertips, using vibrators following the design of Sherrick (1965). The Sherrick vibrators were enclosed in a 7.6cm X 12.7cm X 7.6cm plexiglass housing (Plate 3). They were reliable and no problems were encountered during the tests.

Reaction times were controlled and displayed by a system which included a clock counter (Hunter Electronics, Series D); a voice reaction time switch (Lafayette Electronics, Model 6620 AO); and a pair of EFI receive/transmit microphone earphones. These components were coupled to the KIM-1 microprocessor.

*This experience has taught us to design future interfaces to the natural contour of the hand.

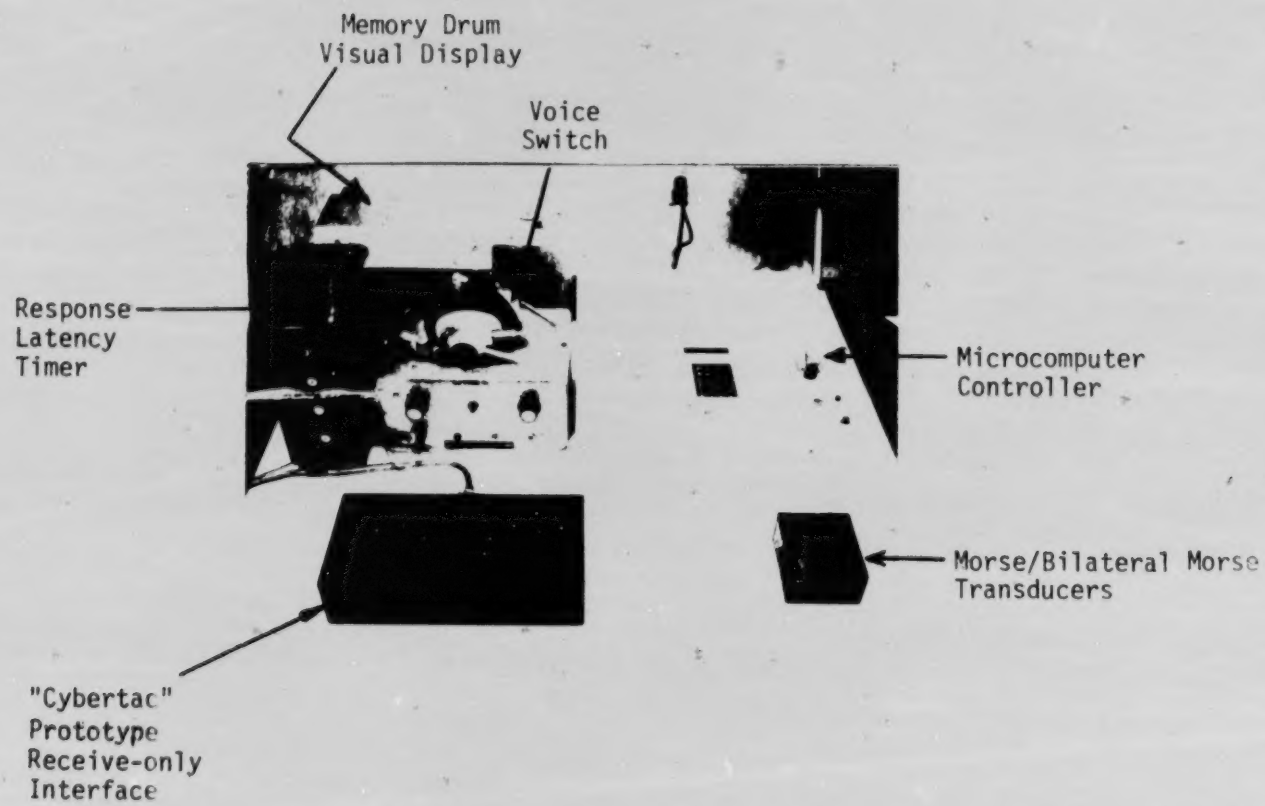
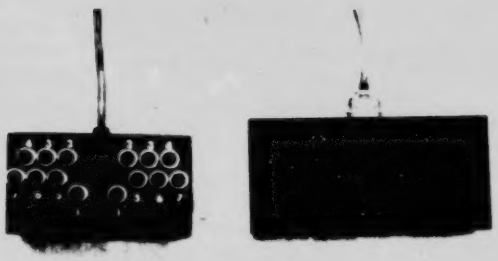



Plate 1. DEBLICOM Pilot Study Apparatus

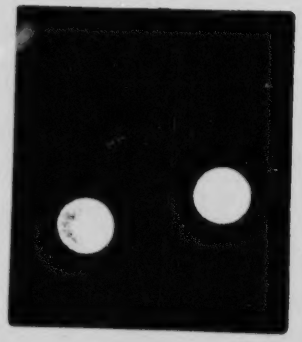
(a)



(b)

Plate 2. (a) Standard CYTERTYPE® 14-Key Finger Interface
(b) DEBLICOM 16-Key "Cybertac" Prototype Receive-only Interface

Plate 3. Morse/Bilateral Morse Transducers



(a) [illegible] in Morse Code

(b) [illegible]se in Bilateral Morse Code



Cybernetics Research Institute

Paired visual stimuli were controlled and presented by the timing memory drum (Lafayette Electronics, Model 2305 H) with the lamp visual display illuminated by a Model CDL30, 40W desk lamp positioned 75cm above the viewing screen. The room itself was illuminated with fluorescent lighting located in the ceiling.

Each subject was seated directly across from the experimenter during the experiment sessions. The subject's view of the experimental equipment was completely obstructed from the memory. The subject's hands were shielded with a 20cm X 40cm foam rubber cover to eliminate visual cues. Plate 4 shows three views of the DEBLICOM "Cybertac" interface: (a) The stand-alone interface; (b) the neutral hands-on position; and (3) the operating position.

The Condition I group of subjects (described in the preceding subsection, "Subjects," at page 11) were presented with the conventional Morse code, in which the index finger of the dominant hand received vibrotactual stimulation of regulation time-sequenced Morse code with a 3:1 ratio of dash-to-dot time-sequencing and a dot-time inter-element interval. (See Figure 3, Test Codes, at page 20).

The subjects in the Condition II group were presented with the cutaneous spatial temporal Morse code, in which the index fingers of both hands received the vibrotactile stimuli with the 'dashes' assigned to the left-hand index finger and 'dots' to the right-hand index finger, with equal time duration for

Plate 4. DEBLICOM 16-Key "Cybertac" Prototype
Receive-only Interface

(a) Neutral Hands-on Position

(b) Operating Position

Figure 3. Test Codes

| TEST CODES* | | |
|---|---|---|
| MORSE CODE | | CYBERCIAC |
| UNILATERAL TEMPORAL | BILATERAL TEMPORAL/SPATIAL | BILATERAL SPATIAL |
| T — | T — | T 1-3 |
| A •— | A — | A 1-4 |
| N —• | N — | N 1-6 |
| I •• | I — | I 1-7 |
| S ••• | S — | S 2-2 |
| H •••• | H — | H 2-3 |
| D —•• | D — | D 2-4 |
| M — — | M — | M 2-7 |
| U ••— | U — | U 3-1 |
| P •— —• | P — | P 3-3 |
| Y —•— — | Y — | Y 3-4 |
| B —••• | B — | B 3-5 |
| J •— — — | J — | J 4-2 |
| K —•— | K — | K 4-3 |
| Z — —•• | Z — | Z 4-6 |
| X —•• — | X — | X 4-7 |
| 3:1, "Dih" to "Dah" time ratio with dot time interelement spacing | 1:1, "Dih" to "Dah" time ratio with dot time interelement spacing<br>"Dih"(Right Side) / "Dah"(Left Side) | 7X7 Bilateral Cybercom Code<br>LEFT SIDE: 4 3 2 / 7 6 5 — 1<br>RIGHT SIDE: 2 3 4 / 5 6 7 — 1 |

*16 randomly selected letters of the 26-character alphabet

dots and dashes and the inter-element interval period.

The subjects in the Condition III group received cutaneous stimuli based on the CYBERCOM code, in which the vibrotactile stimuli were presented in a form different than the conventional Morse codes as introduced in Conditions I and II. Fourteen positions of a 16-position bilateral vibrotactile array were used, with seven for the fingers and thumbs of each hand.

In one phase of the pilot study, a modified variation of the paired-associate learning tasks was utilized in a pilot experiment in which the coded vibrotactile stimuli were paired with 16 randomly selected letters of the English alphabet (see Figure 3, above). This pilot experiment was designed to obtain data for the purpose of evaluating differences in acquisition rates of the coding schemes over the three experimental conditions. Systems under design at C/R/I for testing encompass a full keyboard context in addition to provisions for stimulation by transducers at a plurality of sites with provisions for varying the stimuli's intensity and duration.

## PROCEDURES

So as to control the study time spent on each item, the recall method consisted of a trial composed of two phases: the Learning Phase and the Testing Phase.

## LEARNING PHASE

This phase consisted of coupling vibrotactile stimulation with the corresponding visual stimulation; that is, a vibrotactile code corresponding with a printed capital letter of the alphabet. The vibrotactile stimuli presented to the subject were followed by a 2-second delay before tachistoscopic presentation of the visual stimulus for a 2-second interval.

## TESTING PHASE

The Testing Phase of each trial consisted of presenting the vibrotactile stimuli in random order and allowing the subject an 8-second response interval.

The testing was divided into three sessions, one hour a day for three consecutive days. The first session consisted of 10 trials of eight previously selected letters of the alphabet and their corresponding signals. The second session was 10 trials with eight different elements; while the third session consisted of six trials of 16 previously encountered coded signals. The instructions given to the subjects were constant over each of the three conditions and were as follows:

INSTRUCTIONS

This is an experiment in which you will learn to associate certain selected letters of the alphabet with palpable vibrations on the fingers on your hands. It is important that you follow the instructions to the best of your ability. Should you fail to follow any instructions, be sure to tell me since the interpretation of the results may be affected.

*Conventional Temporal Morse Code*

In front of you is a black box. Would you rest the index finger of your dominant hand (the hand you write with) on the blue button. [Do not press] [Demonstrate]

*Bilateral Spatial Morse Code*

In front of you is a black box. Would you rest the index fingers of both hands on the one box with the blue buttons, that is, your left index finger on the left button and your right index finger on the right button. [Demonstrate]

*CYBERCODE*

In front of you is a black box. Would you place both hands on the box in such a manner so that the fingers on both hands cover all of the white contact points. [Demonstrate]

The pairs will consist of eight or 16 pairs of letters and palpable vibrations [tester activates a letter to demonstrate the palpable tactile stimuli]. These pairs will be presented tactually on the (blue or white) buttons and visually on the window of the display in front of you. When we begin, the tactile stimulation will be generated alone, while the letter to appear in the window will remain unexposed. After a short time the letter will be revealed to you. Your task is to associate or connect the vibratory sensation with the corresponding letters which have been displayed to you so that you will be able to say the letter when the vibration is activated. Since the order in which the letters follow each other will not be the same you must learn to associate their pairs and not the particular order in which the pairs follow each other.

When I begin the testing I will present the vibratory stimulation along with the letter, which you should say out loud when it appears in the window. Remember to study the stimulations and make the association between

the palpable vibrations and the letter; this is the Learning Phase.

After we have gone through the (8 or 16) pairs once, we will repeat the tactile stimulations, when you will be asked to recall the associations made between the tactile sensations and the letter. It is during this second phase—the Testing Phase, when the stimulation is given—that you must begin trying to say the letter that goes with it within a predetermined period of time. You should continue through the test until I ask you to stop. This procedure will be repeated 10 times.

Always try to anticipate the letter just after the vibration sensation has appeared. If you are able to say the letter before the alloted time elapses, it will be counted as correct; on the other hand, if you say nothing or say the letter after the alloted time it will be counted as a miss. Always try to get as many of the pairs correct as you can on each trial, even though you may have them all correct on some of the preceding trials. If you are having trouble anticipating some of the letters or are giving some incorrectly, try not to let this discourage you or prevent you from doing the best you can. We have found that most people find this type of learning a little more difficult than they first thought it would be.

## RESULTS

Figures 4 and 5 illustrate the mean number of the correct responses as a function of the 10 trials in sessions I and II, respectively. The similarity in the learning curves attributed to the separate conditions are remarkably consistent over the first two sessions. On each occasion, the dual-input CYBERCOM code scored beyond a mean of 7 for the tenth trial of each session. Subjects who were exposed to the bilateral spatial Morse code scored an average of 5 correct out of 8 for the final trial in each session, and the subjects receiving conventional temporal Morse code scored 3 of 8 for the final trial during both sessions.

Figure 4. Mean Number of Correct Responses as a Function of 10 Trials in Session I

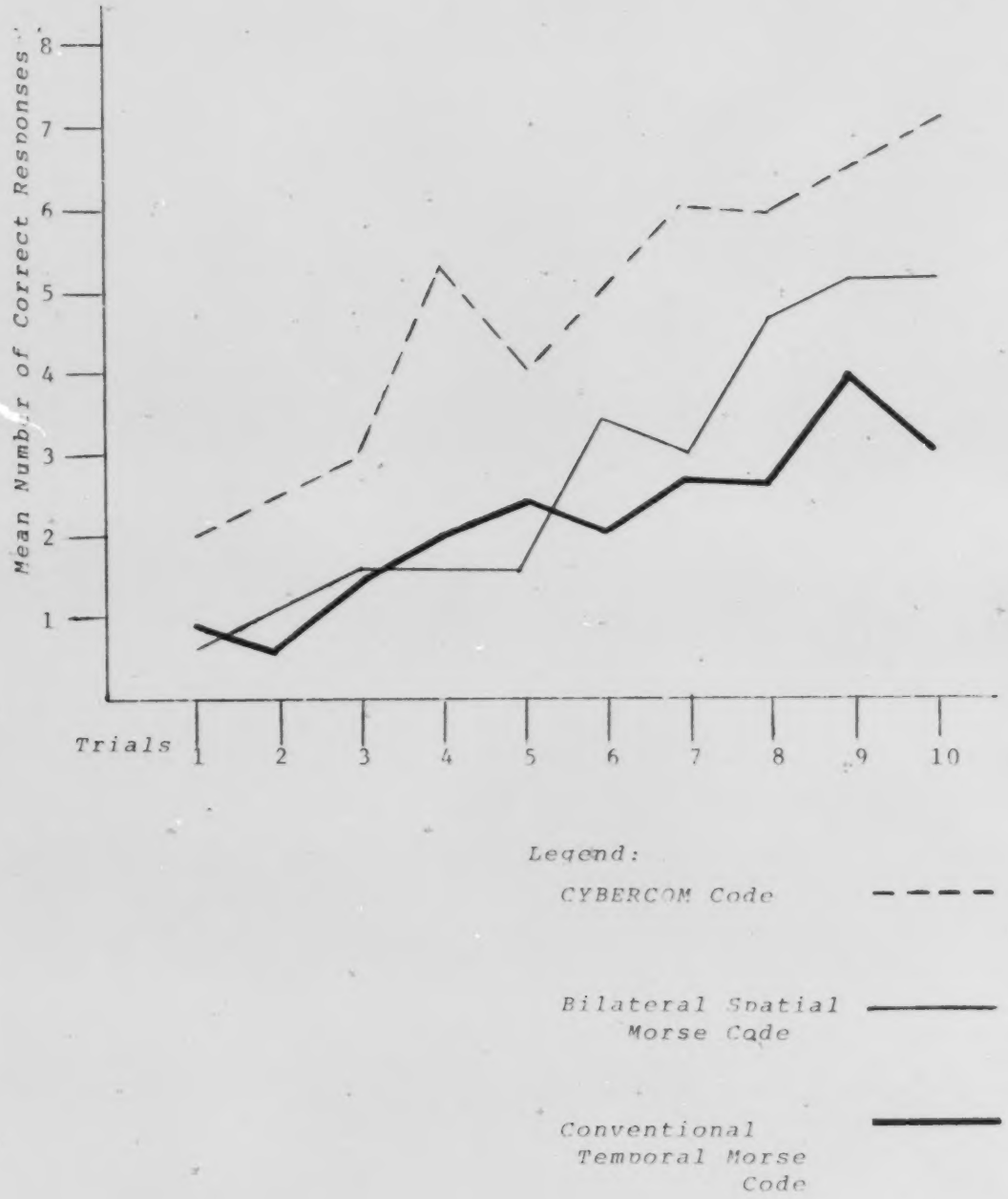
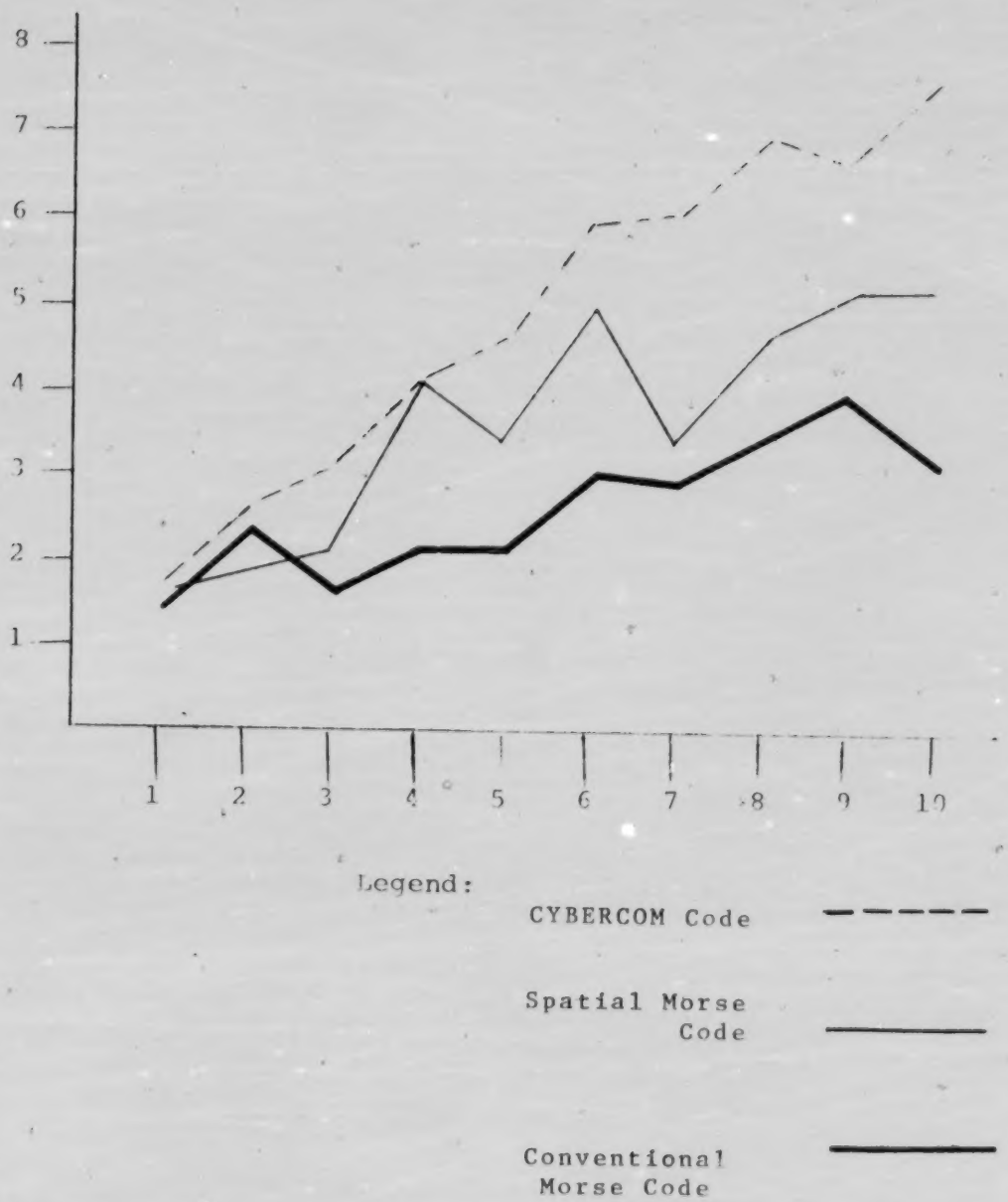
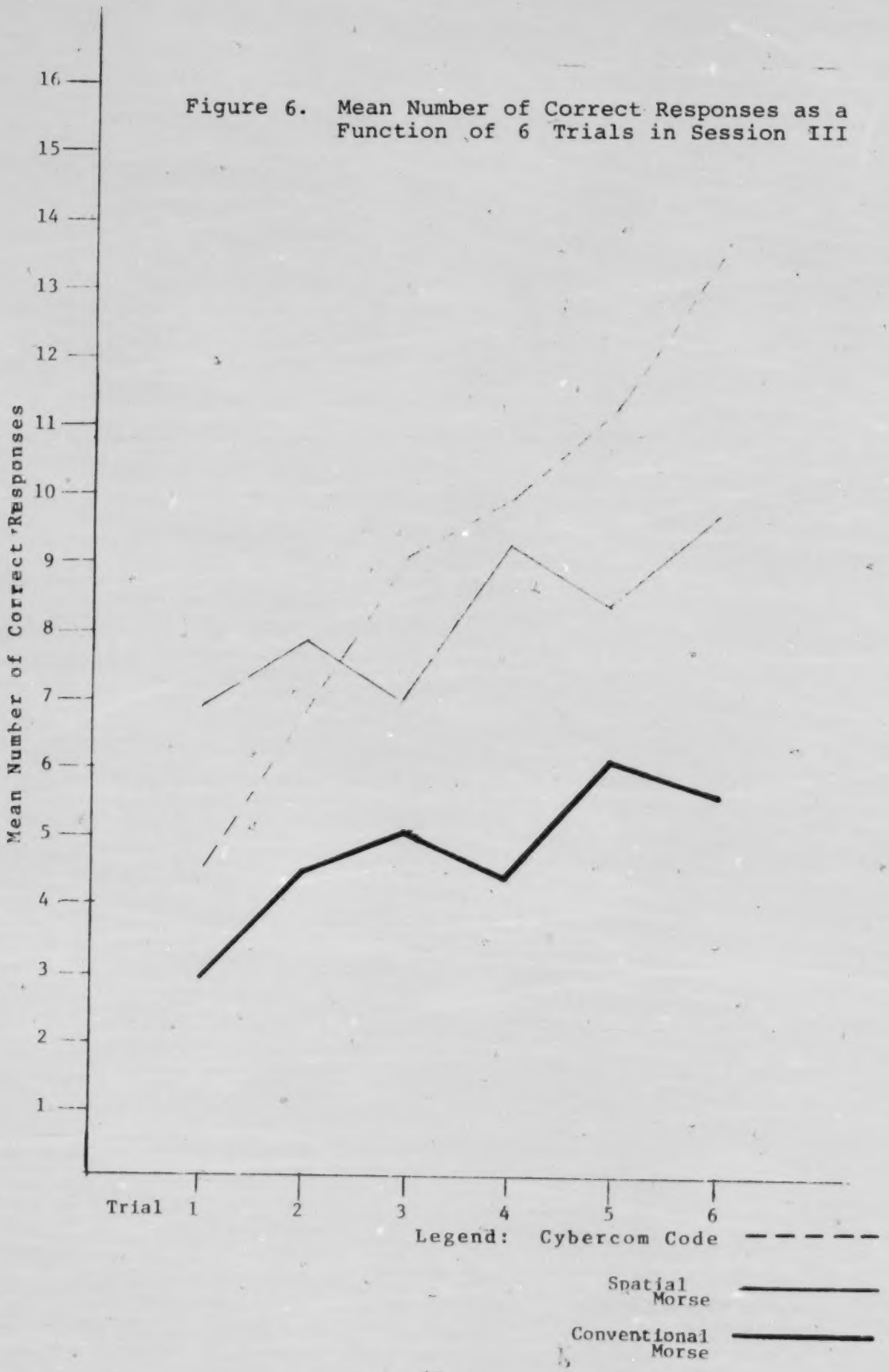


Figure 5. Mean Number of Correct Responses as a Function of 10 Trials in Session II



In Figure 6, the mean number of correct responses recorded as a function of the 6 trials in session III illustrates a learning response curve similar to the first two sessions, with correct responses culminating at 14 out of 16 for the CYBERCOM code; 10 of 16 for the bilateral spatial Morse code; and 5.5 of 16 for the conventional temporal Morse code.

Figure 6. Mean Number of Correct Responses as a Function of 6 Trials in Session III



## CUTANEOUS COMMUNICATIONS CODES—COMPARISONS OF TRANSMISSION RATES OF *DEBLICOM CYBERCOM* CODING AND CUTANEOUS MORSE CODES

The purpose of this section is to present a comparison of the transmission rates of four coding methods which have potential for use in cutaneous communication systems for persons who are deaf-blind.

The coding methods analyzed are the standard Morse; two modifications of the Morse code, identified as Spatial Morse $Code_1$ and Spatial Morse $Code_2$ (Kafafian, 1976); and CYBERCOM code (Kafafian, 1968), a spatial, multiloci, dual-input/output code. The comparisons are made considering that the information transmitted is in the form of English language material.

A cutaneous communication system utilizing Morse code would have a single vibratory transducer presented to the recipient, at one location on the body, sequences of the coded elements consisting of spaces, 'dots,' and 'dashes,' combinations of which represent the transmitted information. The 'length' or duration of a dot is defined as one "unit of time" (u.t.), the duration of the dash as 3 u.t.'s, an inter-element space as 1 u.t., an intercharacter space as 3 u.t.'s, and an interword space as 7 u.t.'s. These timing relationships are shown in Figure 7, page 31.

Both of the spatial Morse codes would require two body locations and two transducers, one for dots and the other for dashes. These two codes differ from the conventional Morse code in that their dots and dashes have the same duration (1 u.t.), so that the distinction between the two code elements

is made by the reception of the information in a spatial rather than on a temporal basis.

Spatial Morse Code$_1$ utilizes an inter-element space of 1 u.t. and intercharacter and interword spaces of 3 u.t.'s and 7 u.t.'s respectively. Spatial Morse Code$_2$ differs from Spatial Morse Code$_1$ only in the area of inter-element spacing within a character. If successive dots or successive dashes are transmitted, an inter-element space of 1 u.t. is used. If, however, a dot is followed by a dash, or a dash by a dot, no inter-element spacing is used. The timing relationships for these two codes are shown in Figure 8.

*Analysis of Transmission Rates*

An analysis of the transmission rates of the three codes was provided in a previous report,* in which the conventional Morse code was used and the spatial Morse code and the CYBERCOM code were developed.

An analysis of a page of text from a C/R/I report** based on the standard time ratios of dots, dashes, intracharacter spaces, intercharacter spaces, and interword spaces yields:

$$\frac{dw}{dt} = \frac{1.5}{t_d} \qquad (1)$$

where: $\frac{dw}{dt}$ = rate of transmission in words per minute

and, $t_d$ = dot time in seconds

*C/R/I Second Quarterly Interim Progress Report, *DEBLICOM—Deaf-Blind Communication & Control Systems* (1976), Rehabilitation Services Administration, Office of Human Development, Dept. of Health, Education, and Welfare, Grant No. 23-P-57488/3-04

**Kafafian; see C/R/I Interim Report, *Study of Man-Machine Communications Systems for the Handicapped* (Aug. 19, 1968), ERIC No. ED 025 890

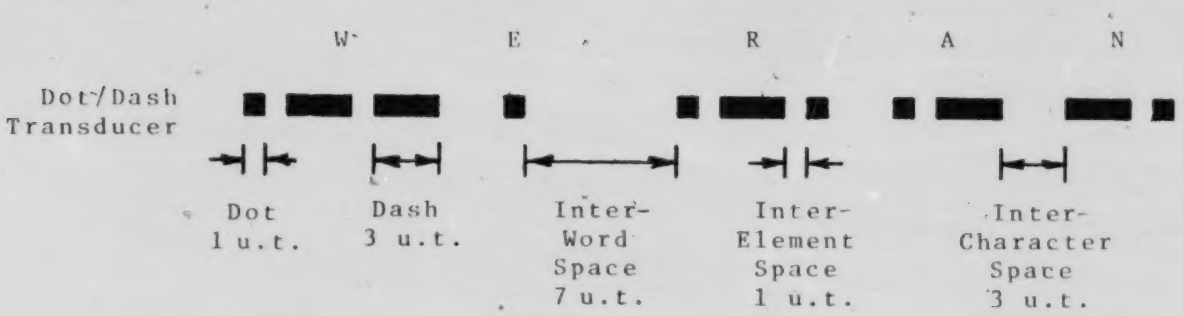
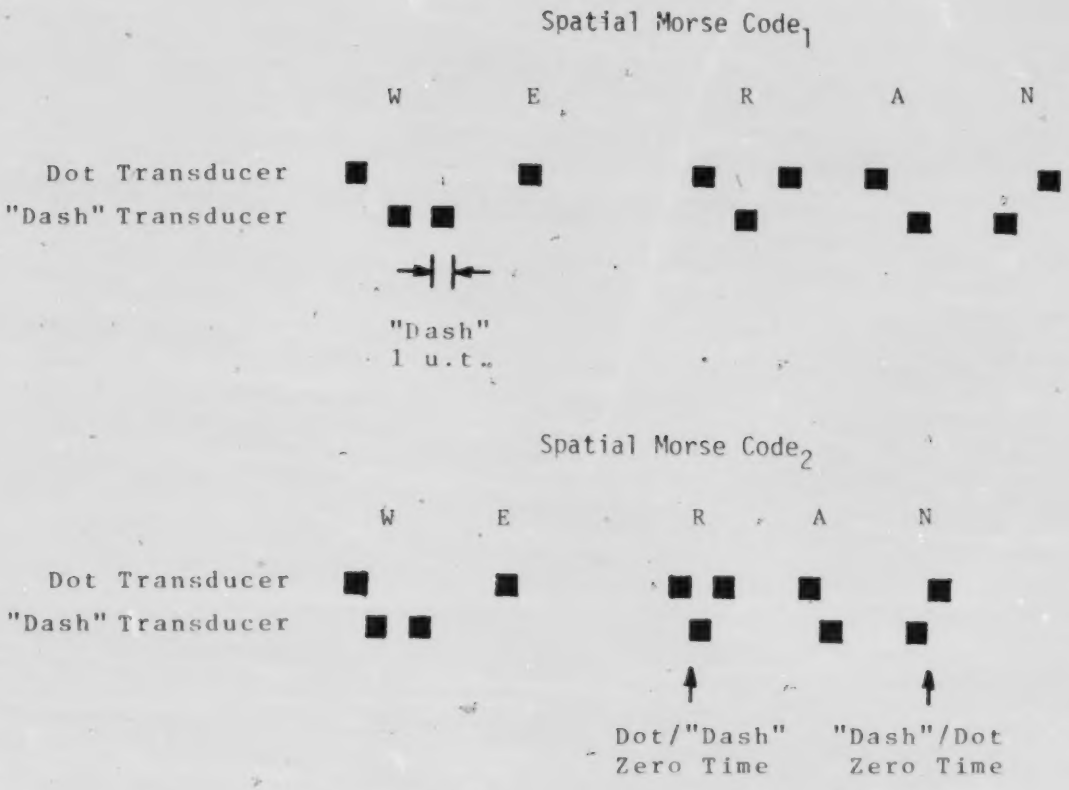



Figure 7. Standard Morse Code Time Relationships




*Other times as in Figure 8*

Figure 8. Spatial Morse Code$_1$ and Spatial Morse Code$_2$ Time Relationships

Thus, for instance, if a dot of 1/10 second duration is used in a Morse code transmission system, the resulting rate of transmission would be 15 words per minute.

Equation (1) agrees favorably with results found elsewhere, such as the data presented by Kahn,* which translates to:

$$\frac{dw}{dt} = \frac{1.3}{t_d} \qquad (2)$$

The objective here is not to establish a precise quantitative relationship between information transmission rate and dot duration for Morse code, but to show that there exists a measurable relationship between communication rate and dot-stimuli duration. It should be noted that the duration of the coded absence of stimuli is essential to a temporal code of the Morse code type.

If parameters other than time duration are used to allow one to discriminate between dots and dashes, an increase in information transmission rate can be realized. For example, in a cutaneous Morse code system in which two different stimulus loci are used to present 'dots' and 'dashes' of equal time duration rather than presentation of regular dots and dashes at a single locus with appropriate time-duration discrimination, analysis of the same text material that led to (1) now yields:

$$\frac{dw}{dt} = \frac{1.86}{t_d} \qquad (3)$$

where: $t_d$ = dot time as well as dash time in seconds

*Kahn, D., *The Codebreakers—The Story of Secret Writing* (The Macmillan Co.: 1967)

Comparison of (3) with (1) shows that a 24 percent improvement in transmission rate can be realized by the use of a spatial discrimination system over that which a time discrimination system will yield for a given dot duration. To our knowledge, this latter approach* has not been tested. It may be worthwhile to determine if it has and, if not, to consider continuation of the original work of Foulke and Brodbeck** with this in mind. Essentially we have introduced a second channel for reception of a portion of the coded elements.

Further analysis of the same page of text leads to the conclusion that the CYBERCOM coding used in the DEBLICOM system should result in more than twice the information rate provided by Morse code in an electrocutaneous or vibrotactile stimulation system, as indicated by:

$$\frac{dw}{dt} = \frac{3.1}{t_d} \qquad (4)$$

Comparison of (4) and (1) shows 107 percent improvement in transmission rate through use of the CYBERCOM code. The rates remain the same with use of one hand or two hands for the temporal and spatial Morse codes. For the CYBERCOM code, the rates analyzed are based on use of loci on both hands.

One DEBLICOM cutaneous code consists of a dual-coding arrangement with seven "left-side" and seven "right-side" transducers. A character or function is represented by the

*Private communication: H. Kafafian and E. Foulke (1976)

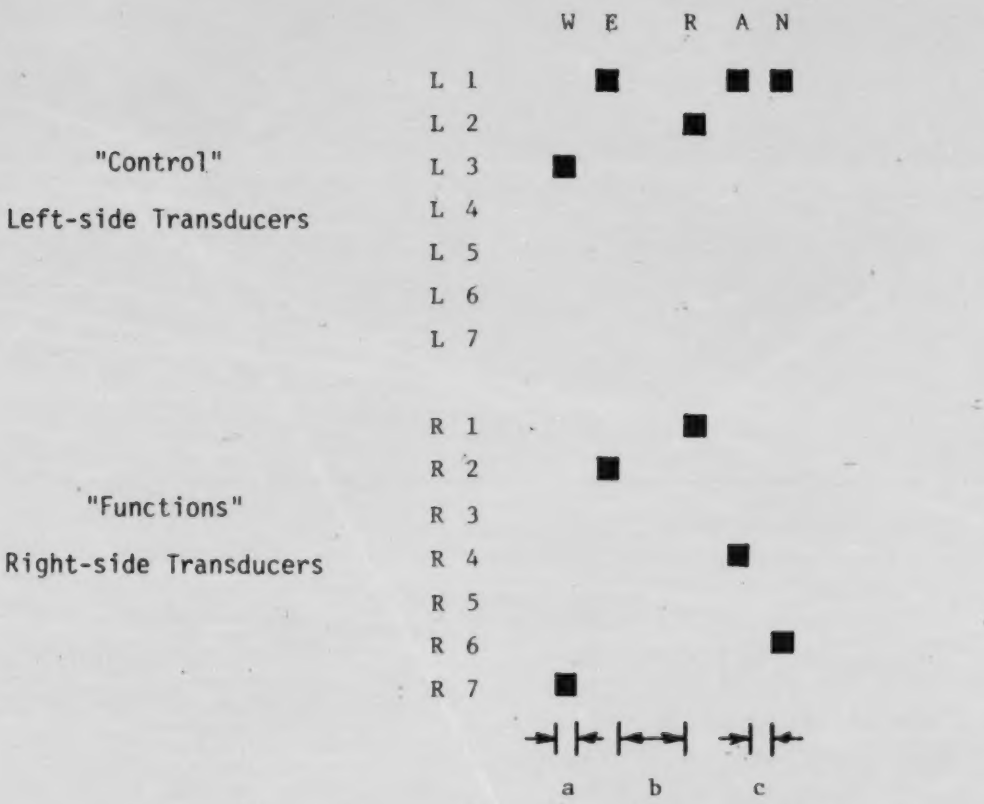
**Foulke, E. and Brodbeck, A.A., "Transmission of Morse Code by Electrocutaneous Stimulation," *Psychological Record* (1968); 617-22.

simultaneous excitation of two transducers, one of the "left-side" combined with one of the "right-side," rather than a series of dots and dashes at only one location. Hence, the time relationships for a transmitted character are considerably different than those for the two types of Morse codes previously described. For CYBERCOM dual-coding, a character is always 1 u.t., an intercharacter space 1 u.t., and an interword space 3 u.t.'s, as shown in Figure 9.

In order to compute transmission rates for English text for these codes, it is first necessary to determine the average duration of each coded character weighted according to its expected frequency of occurrence. Table I presents these weighted average durations and the data used in their determination. The expected frequencies of occurrence were derived from Pierce (1968). (See also Kafafian, Interim Report, *Study of Man-Machine Communications Systems for the Handicapped* (1968)).

Transmission rate computations for the four codes assume an average word length of five characters. These computations and their results expressed as words-per-minute (wpm) per u.t. are shown in Table II. The rates of transmission for the four codes predicated on a u.t. of 0.1 seconds are shown in Table III. Also shown in Table III are the relative rates of transmission in percentages predicated on a constant u.t. and using the standard Morse code as the reference.

For any given u.t.—which is the minimum stimulus duration in use for the selected code—the results presented in Table III




a - Character, 1 u.t.
b - Inter-word space, 3 u.t.
c - Inter-character space, 1 u.t.

Figure 9. CYBERCOM® Code Time Relationships

Table I. Determination of Weighted Average Character Durations for the Four Codes

| | | Character Duration in U.T.'s | | | | Weighted Char. Duration in U.T.'s | | | |
|---|---|---|---|---|---|---|---|---|---|
| (a) Character | (b) Expected Frequency | (c) Morse Code | (d) Spatial Morse | (e) Spatial Morse | (f) CYBER-COM | (g) Standard Morse Code | (h) Spatial Morse Code$_1$ (b)X(d) | (i) Spatial Morse Code$_2$ (b)X(e) | (j) CYBER-COM (b)X(f) |
| E | 0.1266 | 1 | 1 | 1 | 1 | 0.1266 | 0.1266 | 0.1266 | 0.1266 |
| T | 0.0978 | 3 | 1 | 1 | 1 | 0.2934 | 0.0978 | 0.0978 | 0.0978 |
| A | 0.0789 | 5 | 3 | 2 | 1 | 0.3945 | 0.2367 | 0.1578 | 0.0789 |
| O | 0.0776 | 11 | 5 | 5 | 1 | 0.8536 | 0.3880 | 0.3880 | 0.0776 |
| I | 0.0706 | 3 | 3 | 2 | 1 | 0.2118 | 0.2118 | 0.1412 | 0.0706 |
| N | 0.0705 | 5 | 3 | 3 | 1 | 0.3525 | 0.2115 | 0.2115 | 0.0705 |
| S | 0.0631 | 5 | 5 | 5 | 1 | 0.3155 | 0.3155 | 0.3155 | 0.0631 |
| R | 0.0595 | 7 | 5 | 3 | 1 | 0.4165 | 0.2975 | 0.1785 | 0.0595 |
| H | 0.0574 | 7 | 7 | 7 | 1 | 0.4018 | 0.4018 | 0.4018 | 0.0574 |
| L | 0.0394 | 9 | 7 | 4 | 1 | 0.3546 | 0.2758 | 0.1576 | 0.0394 |
| D | 0.0389 | 7 | 5 | 4 | 1 | 0.2723 | 0.1945 | 0.1556 | 0.0389 |
| U | 0.0280 | 7 | 5 | 4 | 1 | 0.1960 | 0.1400 | 0.1120 | 0.0280 |
| C | 0.0268 | 11 | 7 | 4 | 1 | 0.2948 | 0.1876 | 0.1072 | 0.0268 |
| F | 0.0256 | 9 | 7 | 5 | 1 | 0.2304 | 0.1792 | 0.1280 | 0.0256 |
| M | 0.0243 | 7 | 3 | 3 | 1 | 0.1701 | 0.0729 | 0.0729 | 0.0243 |
| W | 0.0215 | 9 | 5 | 4 | 1 | 0.1935 | 0.1075 | 0.0860 | 0.0215 |
| Y | 0.0201 | 13 | 7 | 5 | 1 | 0.2613 | 0.1407 | 0.1005 | 0.0201 |
| G | 0.0187 | 9 | 5 | 4 | 1 | 0.1683 | 0.0935 | 0.0748 | 0.0187 |
| P | 0.0187 | 11 | 7 | 5 | 1 | 0.2057 | 0.1309 | 0.0935 | 0.0187 |
| B | 0.0156 | 9 | 7 | 6 | 1 | 0.1404 | 0.1092 | 0.0936 | 0.0156 |
| V | 0.0102 | 9 | 7 | 6 | 1 | 0.0918 | 0.0714 | 0.0612 | 0.0102 |
| K | 0.0060 | 9 | 5 | 3 | 1 | 0.0540 | 0.0300 | 0.0180 | 0.0060 |
| X | 0.0016 | 11 | 7 | 5 | 1 | 0.0176 | 0.0112 | 0.0080 | 0.0016 |
| J | 0.0010 | 13 | 7 | 6 | 1 | 0.0130 | 0.0070 | 0.0060 | 0.0010 |
| Q | 0.0010 | 13 | 7 | 5 | 1 | 0.0130 | 0.0070 | 0.0050 | 0.0010 |
| Z | 0.0006 | 11 | 7 | 6 | 1 | 0.0066 | 0.0042 | 0.0036 | 0.0006 |
| Weighted Average Character Duration in u.t.'s | | | | | | 6.0496 | 4.0498 | 3.3022 | 1.0000 |

Table II. Determination of Transmission Rates for the Four Codes

| | MORSE CODE | BILATERAL MORSE$_1$ | BILATERAL MORSE$_2$ | CYBERCOM |
|---|---|---|---|---|
| Character Time | = 5 x 6.0496 u.t. = 30.248 u.t. | 5 x 4.0498 = 20.249 | 5 x 3.3022 = 16.511 | 5 x 1 = 5 |
| Inter-character Time | = 4 x 3 u.t. = 12 u.t. | 4 x 3 = 12 | 4 x 3 = 12 | 4 x 1 = 4 |
| Inter-word Time | = 1 x 7 u.t. = 7 u.t. | 1 x 7 = 7 | 1 x 7 = 7 | 1 x 3 = 3 |
| | Word Time = 49.248 u.t. | 39.249 u.t. | 35.511 u.t. | 12 u.t. |
| Transmission Rate = | $\frac{1.218}{\text{u.t.(sec)}}$ wpm | $\frac{1.529}{\text{u.t.(sec)}}$ wpm | $\frac{1.690}{\text{u.t.(sec)}}$ wpm | $\frac{5.0}{\text{u.t.(sec)}}$ wpm |

Table III. Comparison of Transmission Rates of the Four Codes

| Code Code | WPM @ u.t. = 0.1sec. | Comparative Percentages |
|---|---|---|
| Morse Code | 12.18 | 100.0 |
| Bilateral Morse$_1$ | 15.29 | 125.5 |
| Bilateral Morse$_2$ | 16.90 | 138.8 |
| CYBERCOM | 50.00 | 410.5 |

clearly show the advantages of the two spatial Morse codes, and especially that of the CYBERCOM code, over the conventional Morse code arrangement with respect to transmission rates.

One of the considerations in the design of a cutaneous communication system is the proper selection of the type of transducer used for the reception of vibrotactile information. These considerations include their smallness of size, lightness of weight, power consumption, reliability, and effectiveness. For example, systems utilizing either of the two spatial Morse codes or the CYBERCOM code may be implemented with low-cost pulse-type transducers driven by direct current. Moreover, the use of the spatial properties of the integument in providing discrete channels to the cognitive centers through the use of these three codes would result in a system design not requiring stimulus duration discrimination of the transmitted coded elements. In addition, the reduction in circuit complexity of associated hardware and the use of rugged transducers should result in increased system reliability over that of a cutaneous communication system using transducers designed for conventional temporal Morse code.

The results of code acquisition experiments involving the use of Morse code and Spatial Morse $Code_1$ in the vibrotactile mode, and the CYBERCOM code using solenoid-type transducers in the tactile mode, showed that these three approaches to coded cutaneous communications have some degree of merit. Spatial Morse $Code_2$, in either the vibrotactile or tactile mode, has not as yet been investigated and it remains to be determined if this nonsynchronous type of coding can be learned easily

and used as readily as the others, In addition, we have not tested the use of Spatial Morse Code$_1$ in tactile mode. Insight gained from preliminary work on the DEBLICOM system supports continued engineering developments of hardware for use with these and other codes.

## ENGINEERING DESCRIPTION AND FLOWCHARTS

The block diagram of the apparatus used in the code acquisition experiment is shown in Figure 10 (Figures 10-21 begin at page 43). The KIM-1 microprocessor module serves to translate the input signals from the 16 push-button character switches and the mode switch into appropriately timed and sequenced drive signals to the Morse and spatial Morse vibratory transducers, the CYBERCOM code transducer array, and the response latency timer.

The vibratory transducers are driven with a 120Hz signal, sufficiently removed from their 85Hz resonance frequency to avoid serious mechanical damping effects from the subject's finger pressure. The conventional temporal Morse code signal utilizes a dot and inter-element time of 0.1 second and a dash time of 0.3 second. The spatial temporal Morse code signal utilizes dot, inter-element, and dash times of equal duration, 0.1 second.

The push-type solenoids of the CYBERCOM code transducer array are driven with a direct-current signal of 0.1 second duration. The stroke of these solenoids is about 5mm with an

initial force of about 115 grams and a seated, or end-of-stroke, force of about 850 grams.

The overall flowchart of the KIM-1 program for this experiment is shown in Figure 11. Detailed flowcharts for each of the routines specified in Figure 11 are shown in Figures 12-17; and that for the Timer subroutine called by each of the three code routines is shown in Figure 18.

The Initialize and Wait routine defines the input and output ports of the KIM-1, deactivates all outputs, loads the interrupt rector in the required memory location, clears all flags, and puts the microprocessor in a wait loop in which it remains until one of the 16 push-button character switches is actuated. Actuation of any of these switches produces an interrupt request signal to the KIM-1. The vectored interrupt operation of the KIM-1 directs the program to the Interrupt routine.

The Interrupt routine reads and stores the 4-bit code representing the character selected, reads the 2-bit code of the selected operational mode, and, on the basis of the latter, directs the microprocessor program to the appropriate code routine: conventional Morse code, spatial Morse, or CYBERCOM code.

The selected code routine provides the drive signals for the appropriate transducer(s) consistent with the character and operational mode selected. The 100-millisecond Timer subroutine is utilized by each of the code routines to

establish the required timing sequences. After the selected character has been presented to the subject, the code routine in use directs the program to the Return from Interrupt routine.

The Return from Interrupt routine generates a 50-millisecond response latency timer start pulse and directs the program to the wait loop of the Initialize and Wait routine where the KIM-1 idles until the next character push-button is actuated.

The logic shift right (LSR) operation of the KIM-1 module is used in the generation of the time-sequenced drive to the Morse and spatial Morse transducers. The LSR operation results in each bit of the selected 8-bit memory word being shifted into the carry flag C and a zero being shifted into the most significant bit (MSB) location. A graphic illustration of the LSR operation is shown in Figure 19.

An example of the use of the LSR operation in the generation of the letter "P" (dot-dash-dash-dot) in Morse code is illustrated in Figure 20. The binary data representative of the letter "P" is first indicated as it would appear in the accumulator A immediately after having been loaded there from the memory location specified by the "P" push-button switch. Starting with the LSB and reading from right to left, a 0 represents a dot and a 1 represents a dash. Additionally, the next most significant bit location following the last code element representation is loaded with a 1 which is used as an "end of character" indicator. Successive LSR operations are performed on A after each of which the value of A is

determined. If A ≠ 0 (i.e., all bits have not as yet been shifted out of A), the value of C establishes the code element to be generated: a dot if C = 0 or a dash if C = 1. After the fifth shift in the example, the value of A will be zero, indicating "end of character."

The most common embodiment of the bilateral CYBERCOM code used is in a 7X7 array; however, with the limited alphabet used in these particular experiments, only a 4X7 system was required. In the microprocessor, bits B3 and B4 of an 8-bit word are used to binary encode the four left-hand coded elements (L1-L4) and bits B5-B7 are used to encode the seven right-hand elements (R1-R7). Figure 21 offers a description of this coding and shows an example of the CYBERCOM code for the letter "P," which is L3 and R3.

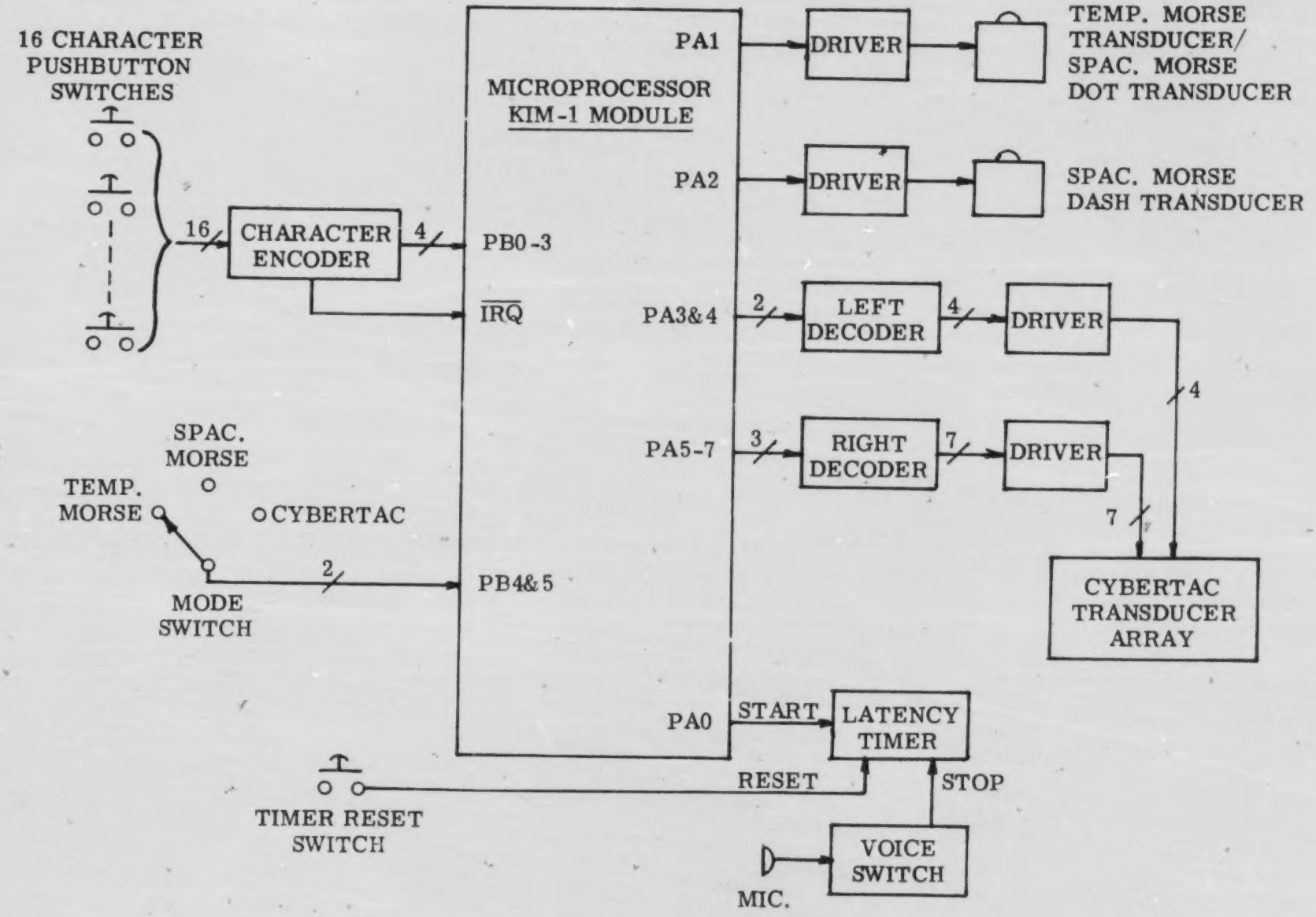



Figure 10. Block Diagram of Microprocessor Systems for Use in Vibrotactile Code Acquisition

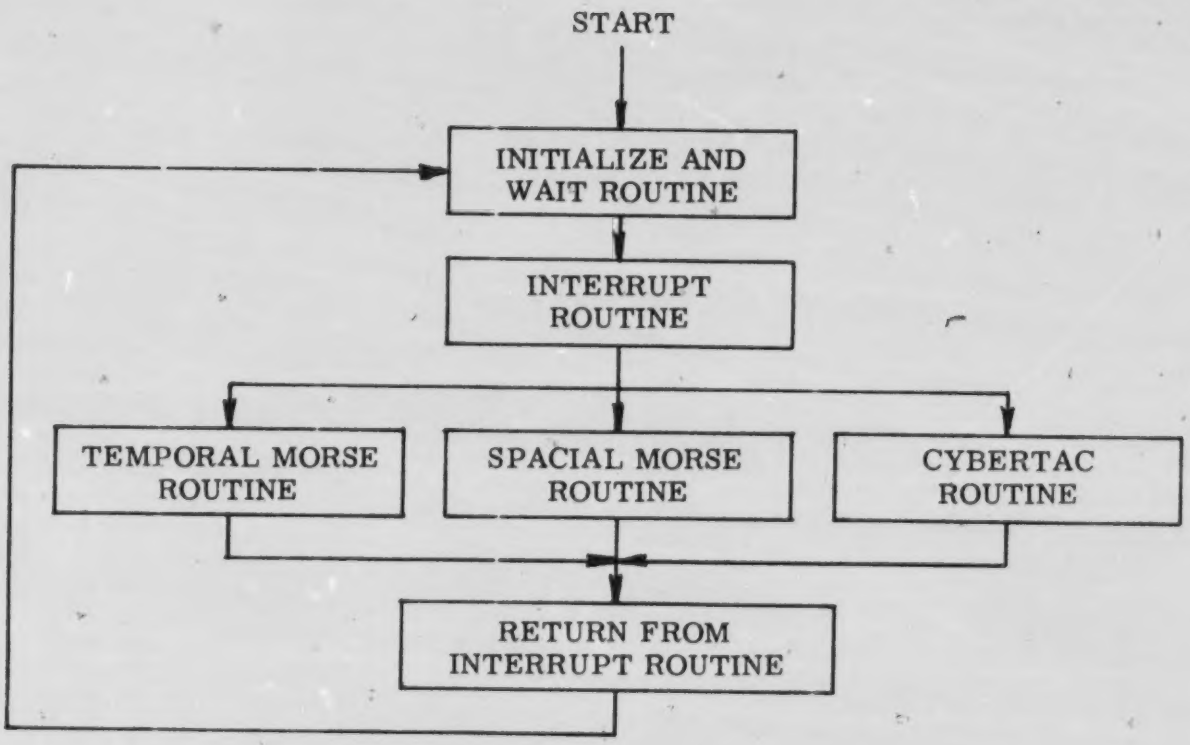



Figure 11. Overall Flowchart of Microprocessor Program for Vibrotactile Code Acquisition Experiment

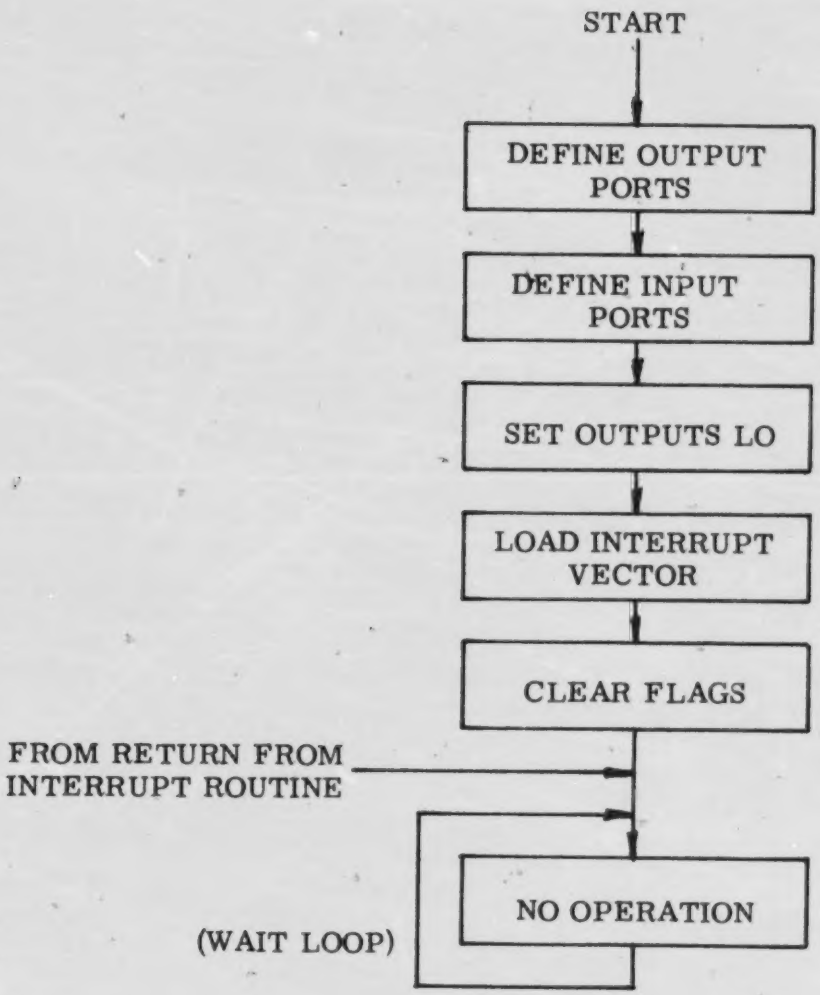



Figure 12. Flowchart of Microprocessor Initialize and Wait Routine

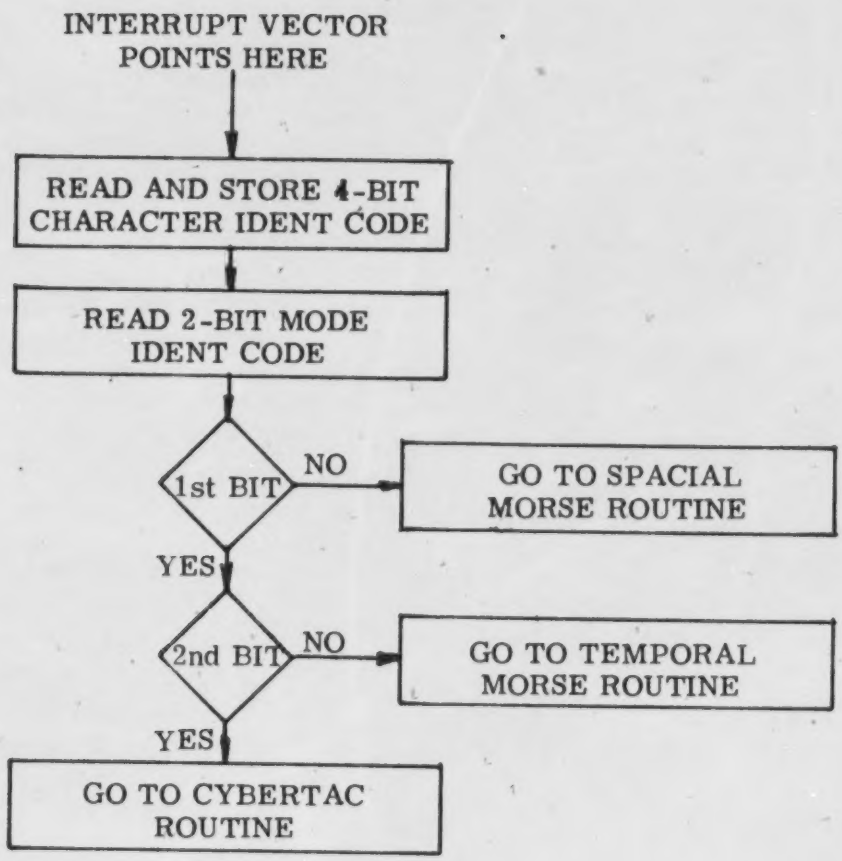



Figure 13. Flowchart of Microprocessor Interrupt Routine

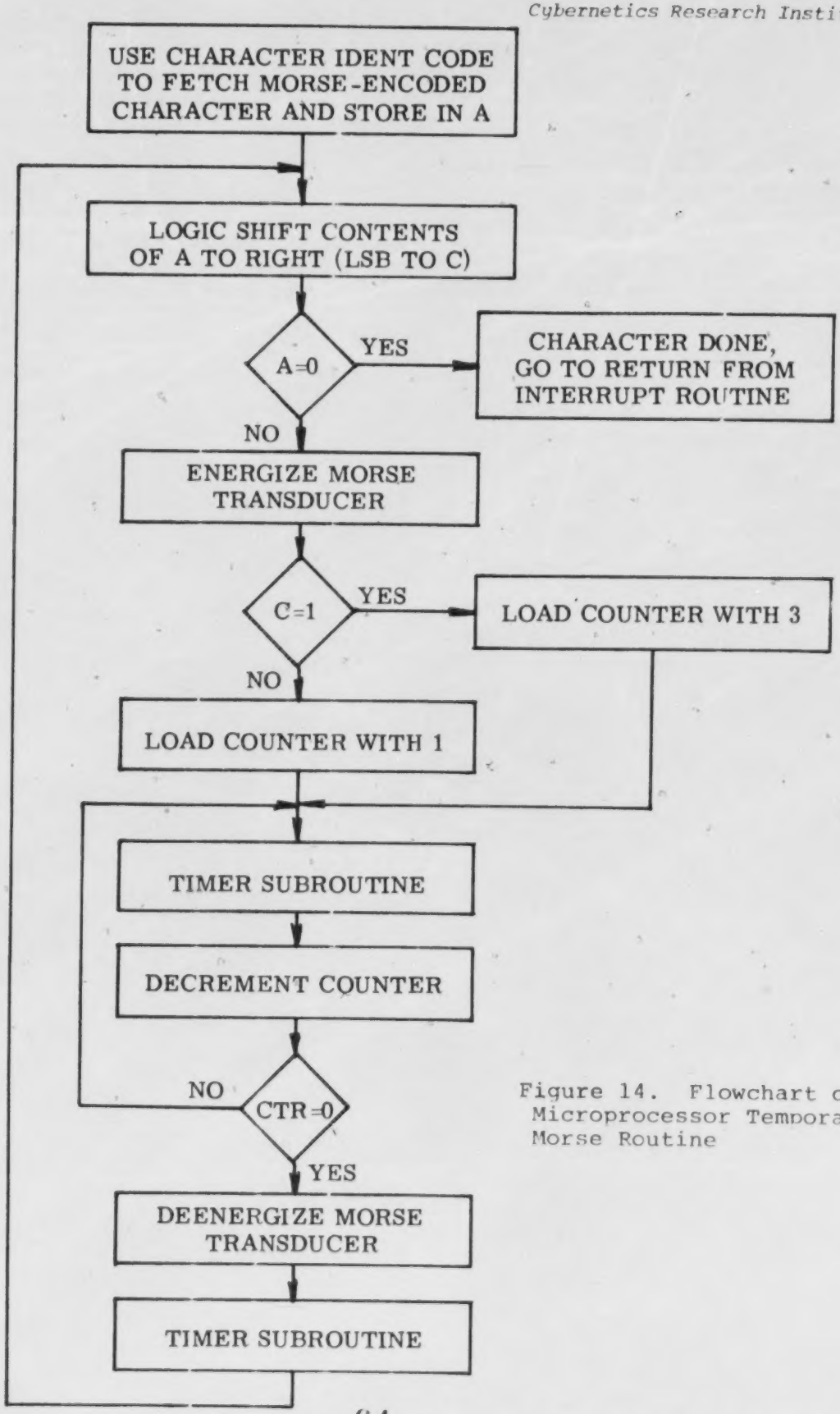



Figure 14. Flowchart of Microprocessor Temporal Morse Routine

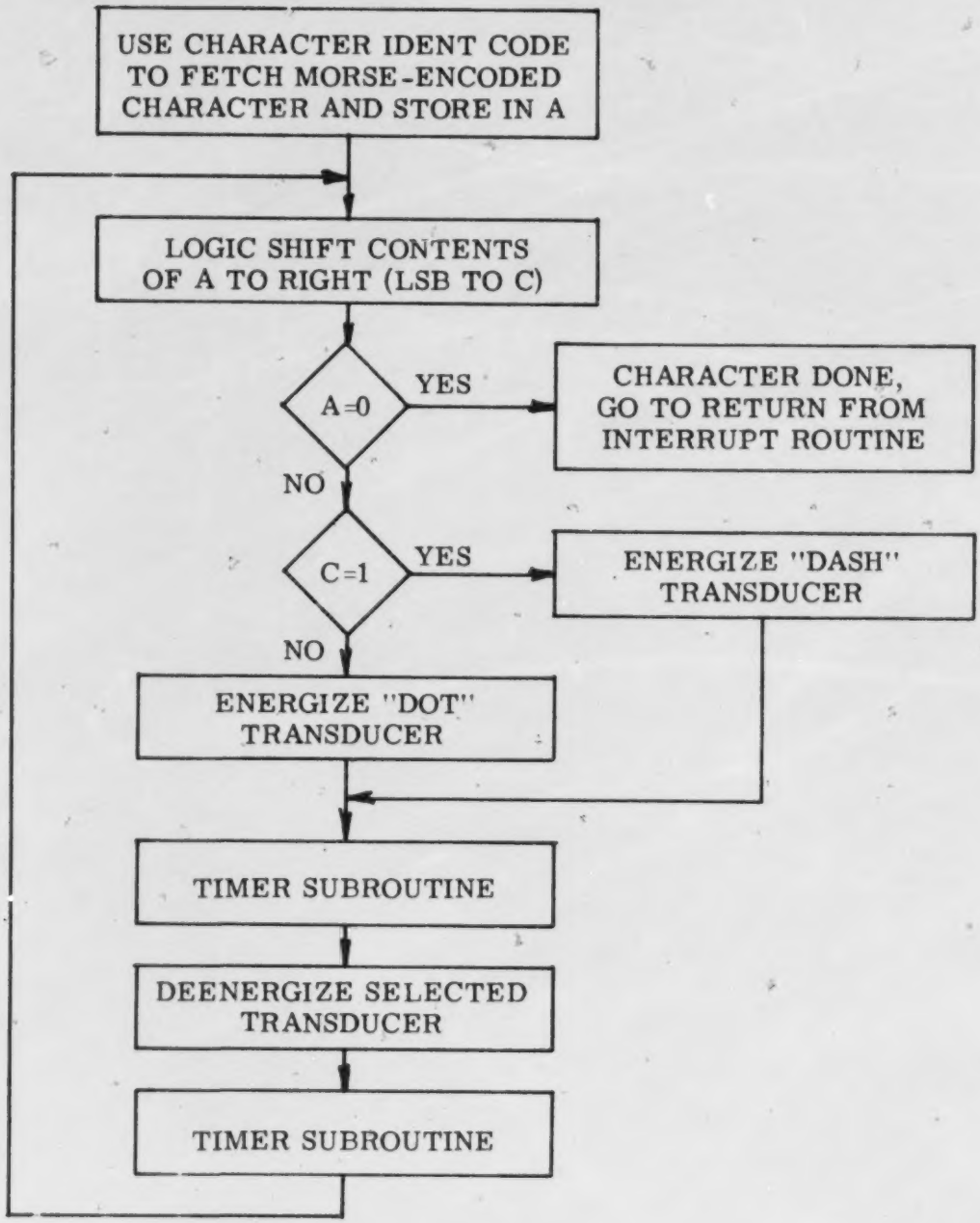



Figure 15. Flowchart of Microprocessor Spatial Morse Routine

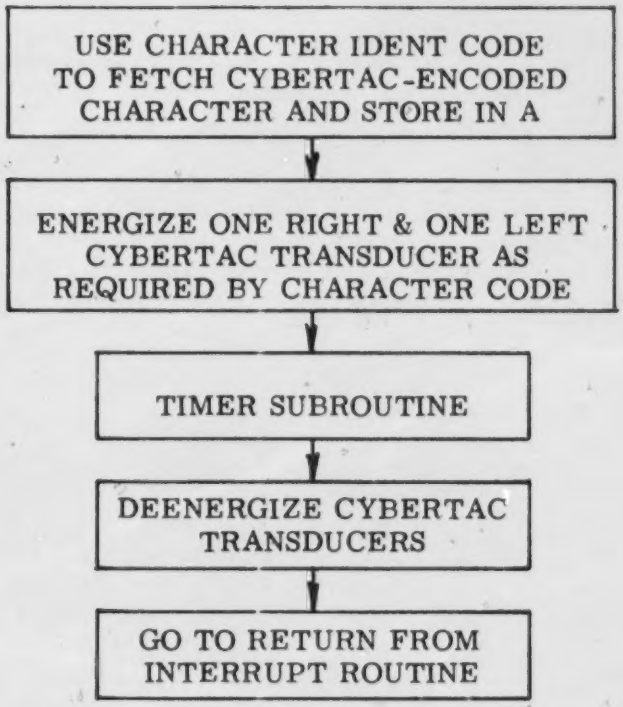

USE CHARACTER IDENT CODE TO FETCH CYBERTAC-ENCODED CHARACTER AND STORE IN A
ENERGIZE ONE RIGHT & ONE LEFT CYBERTAC TRANSDUCER AS REQUIRED BY CHARACTER CODE
TIMER SUBROUTINE
DEENERGIZE CYBERTAC TRANSDUCERS
GO TO RETURN FROM INTERRUPT ROUTINE

Figure 16. Flowchart of Microprocessor "Cybertac" Routine

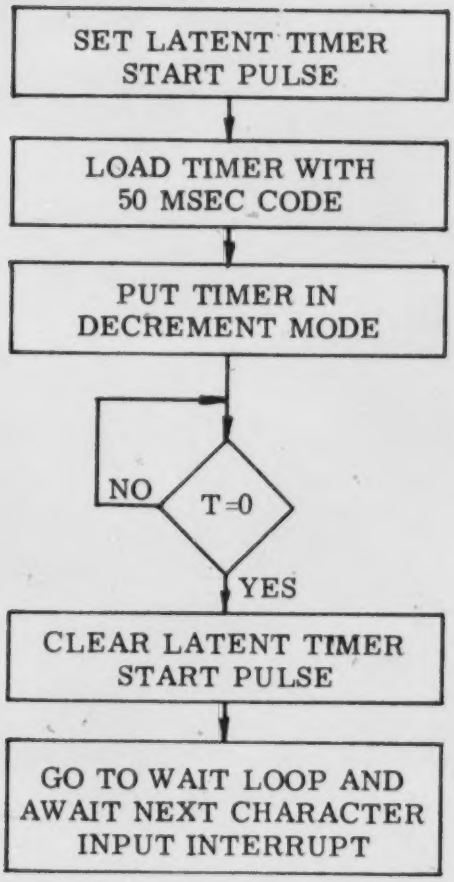

SET LATENT TIMER START PULSE
LOAD TIMER WITH 50 MSEC CODE
PUT TIMER IN DECREMENT MODE
NO
T=0
YES
CLEAR LATENT TIMER START PULSE
GO TO WAIT LOOP AND AWAIT NEXT CHARACTER INPUT INTERRUPT

Figure 17. Flowchart of Microprocessor Return from Interrupt Routine

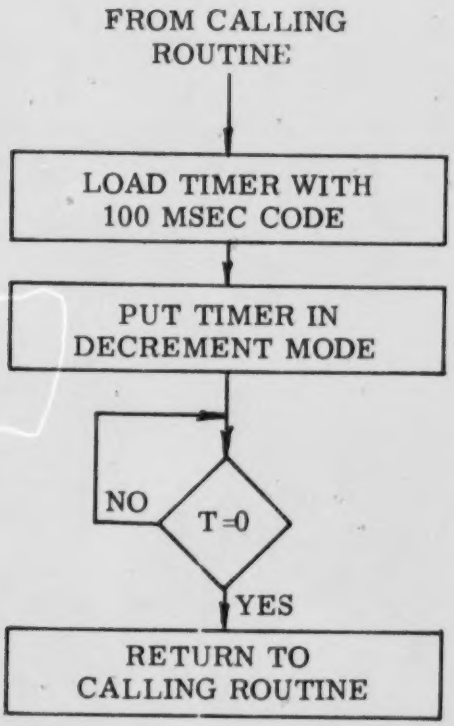



Figure 18. Flowchart of Microprocessor Timer Subroutine

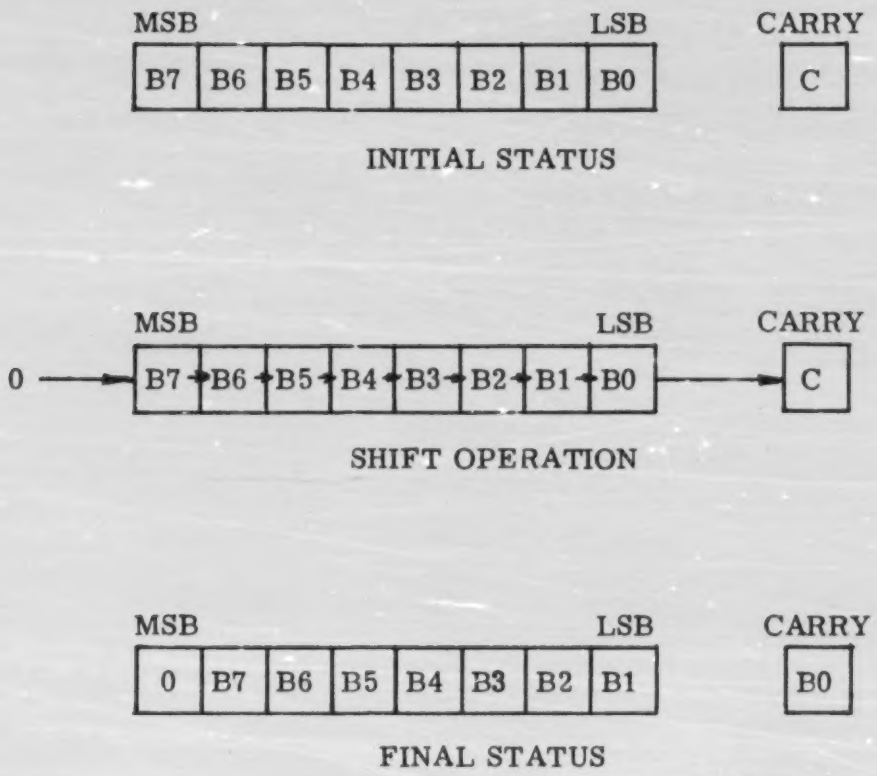



Figure 19. Description of Logic Shift Right Operation of KIM-1 Microprocessor

MORSE CODING FOR LETTER "P": DI DAH DAH DIT

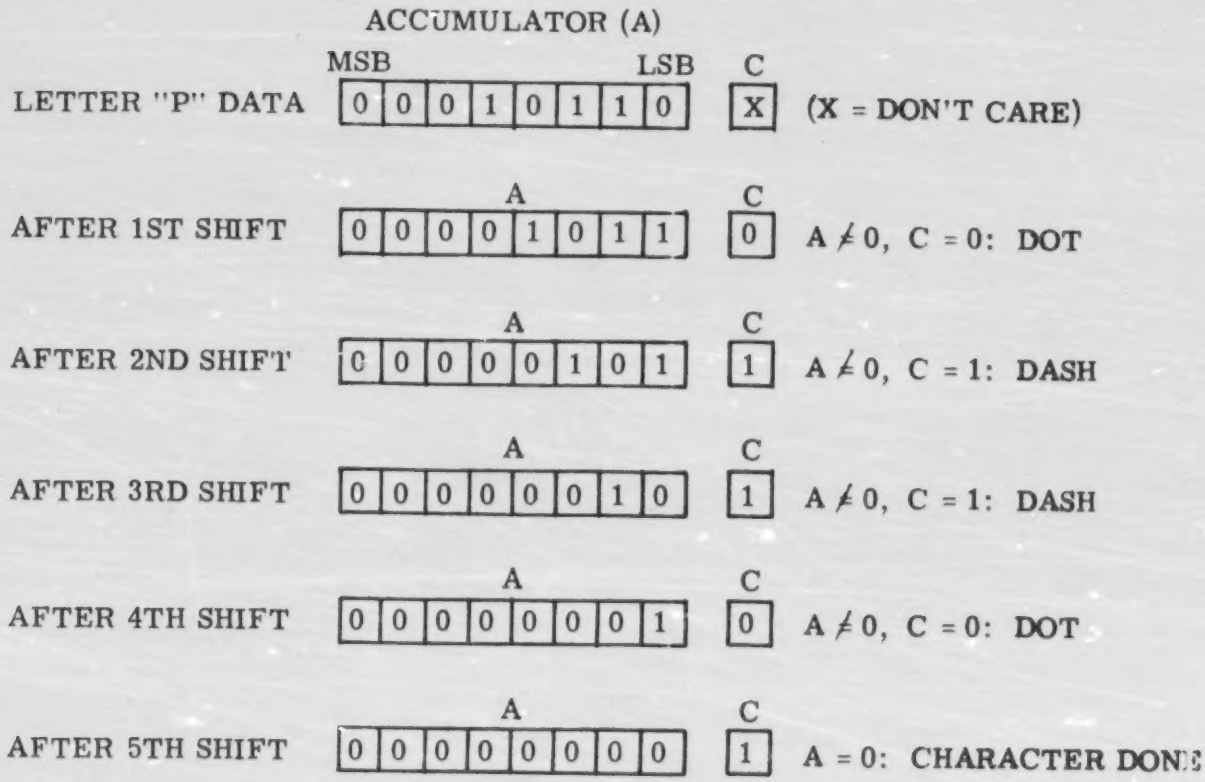



Figure 20. Example of Use of Logic Shift Right Operation in Generation of Letter "P" in Morse Code

| B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 | 8-BIT WORD |
|---|---|---|---|---|---|---|---|---|
| X | X | X | 0 | 0 | X | X | X | L1 CODING (X=DON'T CARE) |
| X | X | X | 0 | 1 | X | X | X | L2 CODING |
| X | X | X | 1 | 0 | X | X | X | L3 CODING |
| X | X | X | 1 | 1 | X | X | X | L4 CODING |
| 0 | 0 | 1 | X | X | X | X | X | R1 CODING |
| 0 | 1 | 0 | X | X | X | X | X | R2 CODING |
| 0 | 1 | 1 | X | X | X | X | X | R3 CODING |
| 1 | 0 | 0 | X | X | X | X | X | R4 CODING |
| 1 | 0 | 1 | X | X | X | X | X | R5 CODING |
| 1 | 1 | 0 | X | X | X | X | X | R6 CODING |
| 1 | 1 | 1 | X | X | X | X | X | R7 CODING |

CYBERTAC CODING FOR LETTER "P": L3 - R3

| 0 | 1 | 1 | 1 | 0 | X | X | X | L3 AND R3 CODING: "P" |
|---|---|---|---|---|---|---|---|---|

Figure 21. Description of CYBERCOM Microprocessor Coding and Example of Generation of Letter "P" for Use with "Cybertac"

RESULTS

The four deaf-blind persons tested in Phase I involved 1,920 trials with a total of 12 errors. This data yields a mean error rate of 0.625 percent (see Figure 22(a)). Analysis of the error rates for the dual-input discrimination tasks, as a function of trial increments, reveal a 1 percent average error for the four subjects tested during the first 50 trials with the remaining trial increments fluctuating between 0.5 percent and 1 percent. Zero errors were recorded for trial increments 301-350. (See Figure 22(b)).

The data from Phase II reveals the apparent tactile pattern discrimination capability on the part of the individuals tested. The mean error rate showed significant consistency, never going beyond 1.0 percent for any of the trial increments.

Figure 23 is a histogram illustrating the percentages of correct responses as a function of the independent conditions. There are 22 percent correct for the conventional temporal Morse code, 43 percent correct for the bilateral spatial Morse code, and 58 percent correct for the CYBERCOM code condition.

The Kruskal-Wallis nonparametric analysis of variance was performed on the data to determine if the variation in the number of correct responses in the individual conditions occurred by chance or were in fact beyond the predetermined acceptable level of significance.

| SUBJECT | SEX | AGE | No. TRIALS | No.ERRORS | ERROR RATES |
|---|---|---|---|---|---|
| 0005 | M | 35 | 480 | 5 | 1.04% |
| 0006 | F | 35 | 480 | 1 | 0.20% |
| 0007 | F | 28 | 480 | 2 | 0.40% |
| 0008 | M | 51 | 480 | 4 | 0.83% |
| | | | 1920 | 12 | 0.63% |

Figure 22(a). Phase II Dual-input Vibrotactile Discrimination Data

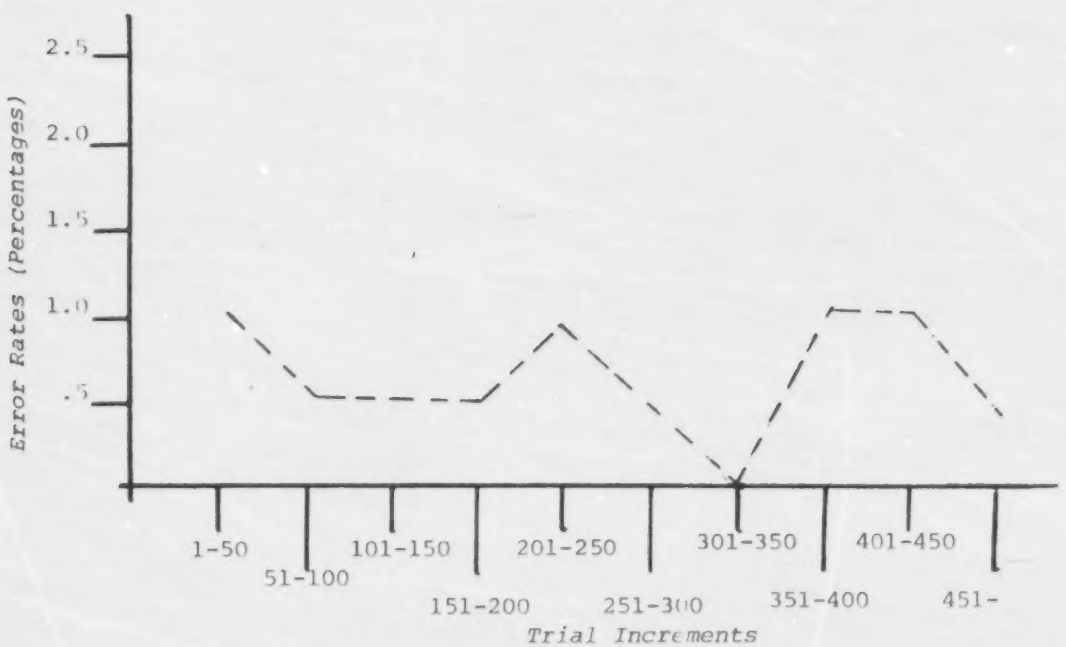



Figure 22(b). Percentages of Errors Made During Distinct Trial Increments in Phase II

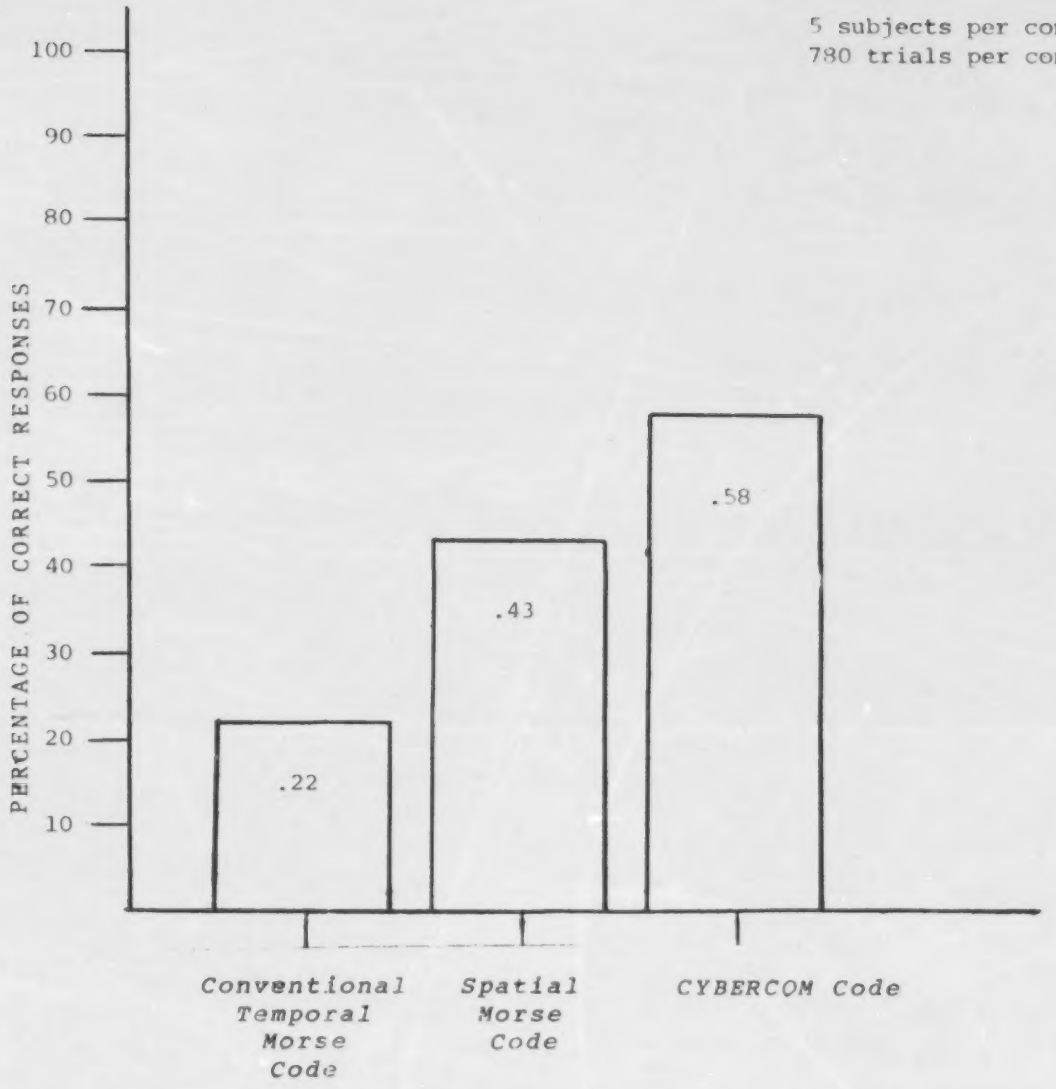



Figure 23. Percentages of Correct Responses as a Function of Code Condition

The data yielded a score beyond a 1-in-20 level of occurring by chance ($H = 6.14 < 0.05$ level).

The Kruskal-Wallis test was followed by another nonparametric statistic: the Mann-Whitney was performed on the sample data to determine exactly where the differences may have occurred across the three conditions. Between the CYBERCOM code and spatial Morse code there was a chance occurrence of 0.075 that the achieved score came from the same population. In spatial Morse code and conventional temporal Morse code the chance occurrence also reached a level of 0.075, while the difference between CYBERCOM code and conventional temporal Morse code was registered at a level of 0.004.

The statistical and graphical data obtained shows clear and uniform indications of difference in subjects' acquisition rates in the three code modalities that were tested. Insight provided by these data on significant differences may be attributed to the increase of cutaneous channels rather than use of one cutaneous stimuli site.

There is sufficient evidence based on the data obtained to continue with the forthcoming phase of implementing multichannel, dual-input/output, cutaneous-kinesthetic codes for two-way communications purposes. Further investigation of codes which embrace the additional elements of intensity, duration, and modulation of stimuli is presently underway at the C/R/I laboratories.

## INTERFACES

There are two styles of DEBLICOM interfaces. One is the touch-feel, portable, finger interface with nothing worn on or attached to the body of a person who is deaf-blind. It is operable in transmit/receive modes. The other is the body receive-only interface.

### "CYBERTAC"* TRANSMIT/RECEIVE FINGER INTERFACE

The touch-feel, DEBLICOM finger interface in its initial design is structured so that a standard 49-key typewriter keyboard is operated by a person who wishes to communicate with the person who is deaf-blind. This keyboard is located adjacent to a 14- or 16-key vibrotactile DEBLICOM touch-feel send and receive keyboard. As a person types a message on the 49-key keyboard its output appears as vibrotactile signals or coded palpable vibrations on the keys of the 14- or 16-key DEBLICOM keyboard. When the person who is deaf-blind operates the DEBLICOM 14-key keyboard, in its transmit mode, its output appears on a display and can be read by persons not visually impaired.

Present plans are to use rechargeable batteries on the DEBLICOM two-way communicator. Structurally the DEBLICOM communicator is not unlike a Tellatouch,** in that it is light and portable.

*C/R/I Interim Report, *Study of Man-Machine Communications Systems for the Handicapped* (Aug. 19, 1968), ERIC No. ED 025 890
**Manufactured by American Foundation for the Blind.

For transmitting information only two of the 14-key interface keys need to be keyed by the fingers and/or thumbs in order to produce one alphanumeric character, symbol, or machine function. In the receive mode the hands are placed on the face of the interface. Two of the transducers are activated in accordance with the very same dual programming codes used to key the interface in the transmit mode and felt by the fingers.

The interface has been designed in order that the integument of the fingers and thumbs can detect any two of the 14 or 16 stimulators which have been activated in accordance with the preassigned dual coding assignments. For example, assume that the letter "E" is to be transmitted by the user. (See Figure 24). This is accomplished by simultaneously striking Key No. 1 with the thumb of the left hand and Key No. 2 with the tip of the index finger of the right hand. If the same letter is to be received by the user, the thumb detects or feels the vibrations of the transducers corresponding to Key No. 1. Simultaneously, the tip of the index finger of the right hand detects the movement of transducers corresponding to Key No. 2. By combining the two interfaces into a single transmit/receive keyboard, a single interface may be used to send and receive coded information in accordance with the dual-input/output code. No transducers are worn on the body with this type of DEBLICOM touch-feel "Cybertac" finger interface.

Provisions in the "Cybertac" interface enable it to accept

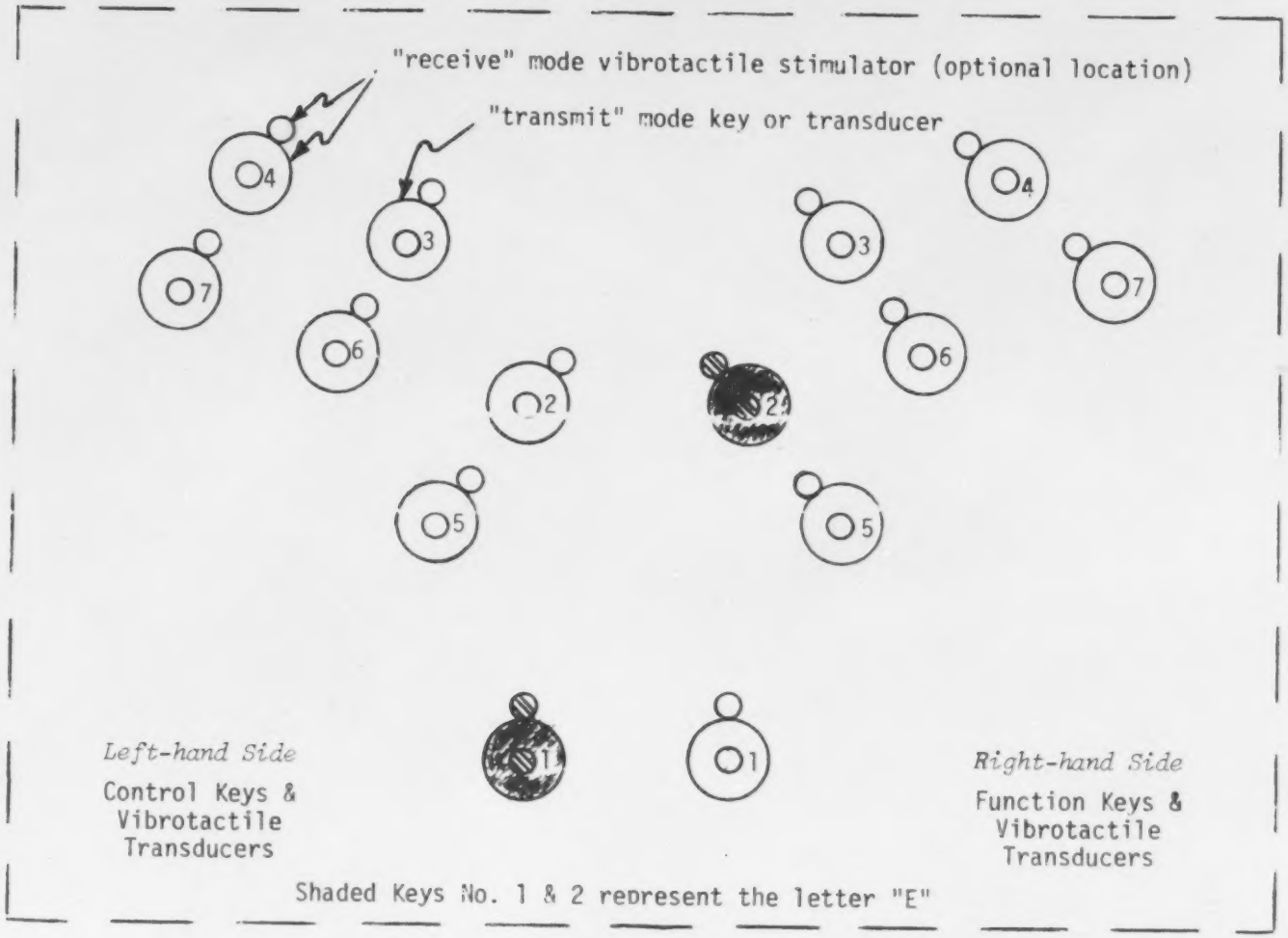



Figure 24. Transmission of the letter "E" on the DEBLICOM Two-way Communicator

additional inputs such as are derived from print and Braille keyboards or from outputs of "pointing," "touch," "message boards," "writing tablets," tape, records, or signals from telephones and other information transfer systems.

In one embodiment, the "Cybertac" interface consists of about 92 functions in which the key configurations are in accordance with the standard American "QWERTYUIOP" key arrangement. The 49-key keyboard, which is essentially of the electromechanical type, consists of switches and solid-state components designed to convert the typed functions over to a vibrotactile interface which in this instance consists of 14 keys and transducers that serve the dual purpose of: (a) a means of keying (in the transmit mode), and (b) as palpable vibrators (in the receive mode).

The "Cybertac" interface is also designed for use by non-disabled individuals having little or no experience with any special codes or keyboards. This consideration enables persons with normal constitutions to directly establish face-to-face two-way communications with persons who are deaf-blind who have learned the "Cybertac" code and who may be speech-impaired. For remote operation, signals from the communicator can be coupled into a standard telephone or into available radio channels assigned for these purposes.

## RECEIVE-ONLY BODY INTERFACE

A second type of DEBLICOM interface is of the style worn on the body consisting of transducers and "Velcro"™* straps. (See Plate 5). These transducers can be quickly attached or removed; they may be worn beneath the user's clothing. They serve only as a means of receiving vibrotactile coded stimuli on the body while the hands may be otherwise occupied. Body transducers principally serve the user in the reception of information and their value is yet to be determined, especially in environments where safety of life or limb is to be considered. Secured by "Velcro"™ straps, the vibrotactile transducers are cable connected to a pocket-sized lightweight signal decoder. These transducers are activated by coding as employed by the portable DEBLICOM "Cybertac" finger interface.

Presently, it appears that cosmetic considerations; i.e., the wearing of body transducers, have negatively influenced a few persons with normal constitutions as well as a few people who are deaf-blind in that they have expressed an opposition to the use of communicatory aids using cutaneous or sub-cutaneous transducers. These misunderstandings should be overcome once the merits and advantages of systems which incorporate these transducers, together with a knowledge of their safety features, are understood. Moreover, there are potentially valuable innovative cutaneous and sub-cutaneous systems under development (e.g., systems used to receive and convert visual, speech or other

*"Velcro"™, trademark

** Bach-y-Rita, 972; Saunders and Collins, 1971; and Sherrick, 1974.

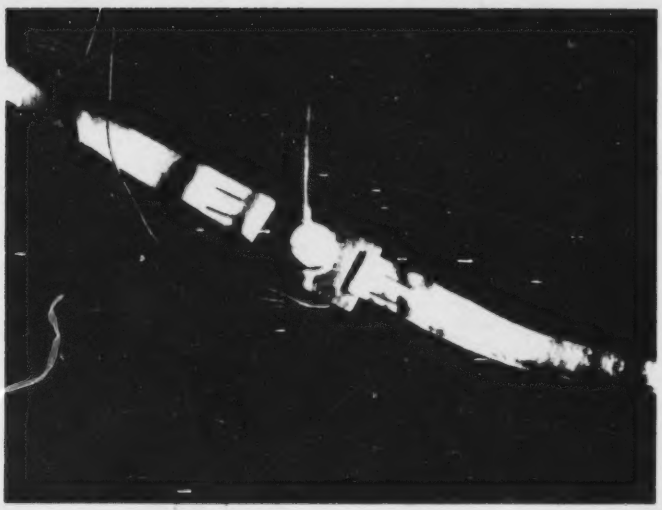


Plate 5. DEBLICOM Prototype Receive-only Body Transducer

information to a cutaneous mode)** for use by persons who are deaf, blind, or deaf-blind which would be of little use if these devices are not made available to investigators who are working toward meeting the critical needs of disabled persons.

The objections, it may have been said, are based on ignorance and unfounded fears. Nevertheless, it is the responsibility of investigators to take special note and not disregard the personal and social aspects to be considered by special educators in preparation of training and instructional materials. On the other hand, it may be noted that we have had no objections to the use of a tactile, finger-controlled, two-way signalling system.

# DEBLICOM System Parts and Materials

The following are the parts and materials required for the DEBLICOM Information Transfer System (DITS) for the period September 1, 1976 - August 1, 1977:

1. PROM Programmers
2. PROM Eraser
3. Microprocessor Assemblies and Software
4. Regulated Power Supplies
5. Memory Subsystems
6. Display Devices and Drivers
7. Integrated Circuits:

   Microprocessor and Peripheral Devices
   PROMS
   Amplifiers
   RAMS
   Interface Elements
   Logic Elements

8. Keyboard Entry Assemblies
9. Switches and Controls
10. Electronic Housings and Hardware
11. Wire, Cable, and Connectors
12. Vibrotactile Transducers and Drivers
13. Electronic and Mechanical Components:

    Vibrotactile Controllers
    Signal Converter Assemblies
    Dedicated Test Apparatus
    Bulk Data Storage

14. Drafting Supplies
15. Printed Circuit Board Materials and Fabrication
16. Integrated Circuit Data Source References
17. Microprocessor Data Source References

# ENGINEERING—LOGIC AND COMPUTER PROGRAMS

## DEBLICOM AUTOMATIC CODE SEQUENCER AND STIMULATOR DRIVER

The engineering effort on the DEBLICOM project has concentrated on the design and fabrication of four DEBLICOM Automatic Code Sequencer and Stimulator Driver (SSD) devices and system elements essential for the psychological tests with subjects using cutaneous codes.

The design of the tests is in progress by Dr. Paul Specter, one of the pioneers in cutaneous communication, in cooperation with C/R/I investigators and Professor John Townsend of The Catholic University of America.

Arrangements have been made through Professor Azriel Rosenfeld of the Computer Vision Laboratory, Computer Science Center, University of Maryland, for free computer time on an 1108 UNIVAC.

Development of suitable vibrotactile transducers and the DEBLICOM Automatic Code Sequencer and Stimulator Driver (SSD) for driving these transducers with the prescribed coded signals stipulated in the test plan were the principal areas of interest during this reporting period.

A visit to Princeton University by Haig Kafafian and James Gouge of C/R/I and Professor Julian Bigelow, permanent member of the Institute of Advanced Study and Chairman Emeritus of C/R/I, resulted in informative discussions with Professor Frank Geldard, Professor Carl Sherrick, and their colleagues.

They confirmed our determination that there are no vibrotactile transducers commercially available which would be suitable for use in the DEBLICOM project. Professors Sherrick and Geldard did provide us, however, with information on two types of transducers which they have designed. One utilizes a solenoid/permanent magnet arrangement which provides a relatively powerful and rugged electromechanical vibration transducer. The other, which makes use of a piezoelectric Bimorph®, is more fragile but smaller, lighter, and requires less electrical power than the first. Adaptations of these two transducers have been designed for use in the DEBLICOM project and are currently under test to ascertain their electrical and mechanical properties and their suitability for use in a vibrotactile communications system.

Concurrently with the design and testing of the transducers, transducer driver and control circuits are being developed and tested. These drivers are solid-state devices capable of computer control and are being designed to interface directly with the SSD.

The heart or, more appropriately, the brain of the DEBLICOM test apparatus is the SSD. This sequencer—stimulator driver is a microprocessor-controlled stored memory device which will provide the test operator with access to the three output modes of signal coding, the code parameter variations, and the code sequences called for in the DEBLICOM test plan.

®Registered trademark of Vernitron, Inc.

The three output modes of signal coding are: (1) DEBLICOM bilateral coding;* (2) Morse code; and (3) spatial Morse code. The last is a unique means of Morse code transmission where two transducers are used, one for 'dashes' and the other for 'dots.' 'Dashes' and 'dots' are of equal time duration (rather than the standard 3:1 ratio) and discrimination between the two is made on a spatial rather than a temporal basis. The results of an earlier C/R/I pilot study** indicate that spatial Morse code allows a faster learning rate than that achievable with standard Morse code.

The source of the code sequence to be output by the SSD can be selected by the test operator to be either: (1) Stored memory; (2) direct keyboard entry; or (3) stored keyboard entry (i.e., the codes to be output are sequentially entered in memory by the operator and then output to the subject on operator command). A visual display will indicate the output signal codes to the operator as they are presented to the subject.

Code parameters under control of the operator are: (1) Duration of stimulation; (2) intensity of stimulation; (3) frequency of stimulation; and (4) time between onsets of coded signals (i.e., rate of presentation to the subject).

Control of the SSD vibrotactile transducer drivers, program sequencing, and code generation are all under software control of the microprocessor as commanded by the stored programs. The development of the software; i.e., controller programs, is a

*Also referred to as "Cybertac" or CYBERCOM coding in this report.
**See "Cutaneous Communications Codes—Comparisons of Transmission Rates, Etc.," at p. 29 of this report.

major element of the DEBLICOM program engineering effort.

The extent of the software development required is such that hand assembly of machine-language programs is impractical. A computer development system (CDS) based on an MITS, Inc. Altair®* 8800B microcomputer has been assembled at C/R/I as a design tool to simplify and speed up the process of software development.

The use of the CDS and the software package provided with it allows C/R/I investigators to write programs at the assembly language level; machine assemble these programs into object code programs readable by the microprocessor; run and debug newly assembled programs; and modify, edit, and rerun debugged programs, all under computer control without human intervention.

The configuration of the CDS includes:

- The 8800B main frame.
- 16k bytes of read/write memory.
- 2k bytes of PROM (programmable read-only memory).
- A serial I/O port for communication with the Lear-Siegler ADM-3A CRT terminal.
- Four parallel I/O ports for driving and controlling the developmental models of the SSD vibrotactile transducer drivers.
- A modem/serial I/O port for storing developed programs on and recovering them from an audio cassette recorder.

## COMPUTER DEVELOPMENT SYSTEM ROUTINES

Pages 71-82 are programs written for the computer development system. Itel®** mnemonics are used throughout.

*Altair®, registered trademark of MITS, Inc.
**Itel(), registered trademark of Intel Corporation, Santa Clara, California.

ROUTINES

```
;MHX - MEMORY HEX DUMP ROUTINE.
;
;THIS ROUTINE ASKS FOR A START & A FINAL ADDRESS
;IN OCTAL.  A CR IS EXPECTED AFTER EACH ADDRESS
;ENTRY.  A "G" IS REQUIRED AFTER THE FINAL ADDRESS
;CR TO BEGIN THE PRINTOUT.  AN "E" ENTERED AT ANY
;TIME PRIOR TO THE ABOVE "G" WILL RESTART THE ADD-
;RESS ENTRY.  ONCE PRINTOUT HAS BEGUN AN "S" WILL
;HALT IT & A "G" WILL RESTART IT  - AN "ESC" WILL
;CAUSE JUMP TO MONITOR.  PRINTOUT IS 16 BYTES PER
;LINE WITH ADDRESSES IN HEX.
;
;
          ORG     25310Q
FIRST     EQU     25013Q
LAST      EQU     25035Q
CTPIN     EQU     24000Q
CNVRT     EQU     24051Q
MHXDMP:   LXI     B,40Q
          LXI     H,STACK
          DAD     B
          SPHL
          CALL    CTPIN
          LXI     H,FIRST
          LXI     D,LAST
          MOV     A,L
          ANI     10Q
          JZ      FRST
          MVI     C,1
          MVI     B,33
SPOVR:    CALL    SPACE
          DCR     B
          JNZ     SPOVR
          JMP     SECND
FRST:     MVI     C,2
SECND:    MOV     A,L
          ANI     7
          JZ      BYTE1
          PUSH    D
          MOV     D,A
          MVI     B,10Q
INCR:     CALL    SPACE
          CALL    SPACE
          CALL    SPACE
          DCR     B
          DCR     D
          JNZ     INCR
          POP     D
          JMP     BYTE2
BYTE:     MVI     C,2
BYTE1:    MVI     B,10Q
```

```
BYTE2:  MOV     A,H
        CALL    HEX
        MOV     A,L
        CALL    HEX
        CALL    SPACE
        CALL    SPACE
BYTE3:  MOV     A,M
        CALL    HEX
        CALL    SPACE
        MOV     A,H
        CMP     D
        JNZ     XRAY
        MOV     A,L
        CMP     E
        JNZ     XRAY
        MVI     A,15Q
        CALL    CNVRT
        JMP     MON
XRAY:   INX     H
        DCR     B
        JNZ     BYTE3
        DCR     C
        JNZ     ADSPC
        MVI     A,15Q
        CALL    CNVRT
        JMP     BYTE
ADSPC:  CALL    SPACE
        CALL    SPACE
        CALL    SPACE
        JMP     BYTE1
SPACE:  MVI     A," "
        JMP     CNVRT
HEX:    PUSH    PSW
        PUSH    B
        MOV     B,A
        RRC,RRC,RRC,RRC
        CALL    HEXAS
        MOV     A,B
        CALL    HEXAS
        POP     B
        POP     PSW
        RET
HEXAS:  ANI     0FH
        ADI     90H
        DAA
        ACI     40H
        DAA
        JMP     CNVRT
STACK:  DS      40Q
        BEG     MHXDMP
        END     MHX
```

MHX - MEMORY HEX DUMP ROUTINE

```
2AC8  01 20 00 21 74 2B 09 F9
2AD0  CD 00 28 21 C8 2A 11 93    2AD8  2B 7D E6 08 CA ED 2A 0E
2AE0  01 06 21 CD 53 2B 05 C2    2AE8  E3 2A C3 EF 2A 0E 02 7D
2AF0  E6 07 CA 0D 2B D5 57 06    2AF8  08 CD 53 2B CD 53 2B CD
2B00  53 2B 05 15 C2 F9 2A D1    2B08  C3 0F 2B 0E 02 06 08 7C
2B10  CD 58 2B 7D CD 58 2B CD    2B18  53 2B CD 53 2B 7E CD 58
2B20  2B CD 53 2B 7C BA C2 36    2B28  2B 7D BB C2 36 2B 3E 0D
2B30  CD 29 28 C3 40 00 23 05    2B38  C2 1D 2B 0D C2 47 2B 3E
2B40  0D CD 29 28 C3 0B 2B CD    2B48  53 2B CD 53 2B CD 53 2B
2B50  C3 0D 2B 3E 20 C3 29 28    2B58  F5 C5 47 0F 0F 0F 0F CD
2B60  69 2B 78 CD 69 2B C1 F1    2B68  C9 E6 0F C6 90 27 CE 40
2B70  27 C3 29 28 CF 28 12 12    2B78  46 10 10 32 CF 28 56 6C
2B80  02 6C CF 28 56 6C 02 02    2B88  88 2B 9A 28 17 20 01 02
2B90  90 2B 24 2B
```

```
;ADR - ADDRESS ROUTINE
;
;THIS ROUTINE ASKS FOR A START & A FINAL ADDRESS
;IN OCTAL & RETURNS WITH START IN HL & FINAL IN
;DE.  A CR IS EXPECTED AFTER EACH ADDRESS ENTRY.
;AN "E" AT ANY TIME WILL RESTART THE ROUTINE AND
;A "G" IS REQUIRED AFTER THE FINAL ADRESS CR TO
;RETURN TO THE CALLER.
;
;
          ORG     175000Q
          ORR     25000Q
ADDRS:    PUSH    PSW
          PUSH    B
ADDRS1:   MVI     A,15Q
          CALL    CRTOT
          MVI     A,12Q
          CALL    CRTOT
          CALL    CRTOT
          LXI     H,START
CRTFST:   MOV     A,M
          ANA     A
          JZ      FSTAD
          CALL    CRTOT
          INX     H
          JMP     CRTFST
FSTAD:    LXI     H,0
FSTAD1:   CALL    INPUT
          CPI     15Q
          JZ      SWTCH
          CPI     "E"
          JZ      ADDRS1
          SUI     60Q
          CALL    HL08
          JMP     FSTAD1
SWTCH:    XCHG
          MVI     A,12Q
          CALL    CRTOT
          LXI     H,FINAL
CRTLST:   MOV     A,M
          ANA     A
          JZ      LSTAD
          CALL    CRTOT
          INX     H
          JMP     CRTLST
LSTAD:    LXI     H,0
LSTAD1:   CALL    INPUT
          CPI     15Q
          JZ      SWTCH1
          CPI     "E"
          JZ      ADDRS1
```

```
            SUI     60Q
            CALL    HL08
            JMP     LSTAD1
SWTCH1:     XCHG
            MVI     A,12Q
            CALL    CRTOT
OK?:        IN      20Q
            RAR
            JNC     OK?
            IN      21Q
            CPI     "G"
            JZ      CALLER
            CPI     "E"
            JZ      ADDRS1
            JMP     OK?
CALLER:     MVI     A,15Q
            CALL    CRTOT
            MVI     A,12Q
            CALL    CRTOT
            POP     PSW
            POP     B
            RET
INPUT:      IN      20Q
            RAR
            JNC     INPUT
            IN      21Q
            OUT     21Q
            RET
HL08:       DAD     H
            DAD     H
            DAD     H
            ADD     L
            MOV     L,A
            RET
CRTOT:      MOV     B,A
CRTOT1:     IN      20Q
            RAR,RAR
            JNC     CRTOT1
            MOV     A,B
            OUT     21Q
            RET
START:      DB      "START ADDRESS ",0
FINAL:      DB      "FINAL ADDRESS ",0
            BEG     ADDRS
            END     ADR
```

ADR - ADDRESS ROUTINE

```
2A00  F5 C5 3E 0D CD 9C FA 3E    2A08  0A CD 9C FA CD 9C FA 21
2A10  A8 FA 7E A7 CA 1E FA CD    2A18  9C FA 23 C3 12 FA 21 00
2A20  00 CD 8B FA FE 0D CA 36    2A28  FA FE 45 CA 02 FA D6 30
2A30  CD 96 FA C3 21 FA EB 3E    2A38  0A CD 9C FA 21 B7 FA 7E
2A40  A7 CA 4B FA CD 9C FA 23    2A48  C3 3F FA 21 00 00 CD 8B
2A50  FA FE 0D CA 63 FA FE 45    2A58  CA 02 FA D6 30 CD 96 FA
2A60  C3 4E FA EB 3E 0A CD 9C    2A68  FA DB 10 1F D2 69 FA DB
2A70  11 FE 47 CA 7E FA FE 45    2A78  CA 02 FA C3 69 FA 3E 0D
2A80  CD 9C FA 3E 0A CD 9C FA    2A88  F1 C1 C9 DB 10 1F D2 8B
2A90  FA DB 11 D3 11 C9 29 29    2A98  29 85 6F C9 47 DB 10 1F
2AA0  1F D2 9D FA 78 D3 11 C9    2AA8  53 54 41 52 54 20 41 44
2AB0  44 52 45 53 53 20 00 46    2AB8  49 4E 41 4C 20 41 44 44
2AC0  52 45 53 53 20 00
```

```
;PRT
;FIRST ADDR @ 25414Q
;LAST  ADDR @ 25417Q
;
        ORG     24000Q
FIRST   EQU     26000Q
LAST    EQU     37777Q
STAT    EQU     20Q     ;TERM STAT REG
TERM    EQU     21Q     ;TERM DATA REG
CTPCN   EQU     100Q    ;CTYPE CONT REG
CTPDA   EQU     101Q    ;CTYPE DATA/DDR REGS
PBCN    EQU     102Q    ;PORT B CONT REG
PBDA    EQU     103Q    ;PORT B DATA/DDR REGS
CR      EQU     22Q     ;CTYPE CR CODE
BS      EQU     144Q    ; " BS CODE
TB      EQU     4       ; " TAB CODE
SPC     EQU     154Q    ; " SP CODE
PRD     EQU     66Q     ; " PRD CODE
COM     EQU     44Q     ; " CMA CODE
NULL    EQU     177Q    ; " NULL CODE
LOCK    EQU     2       ; " SHFT LK CODE
UNLOK   EQU     142Q    ; " SHFT UNLK CODE
ESC     EQU     33Q     ;ASCII ESC CODE
STP     EQU     123Q    ; " S CODE
GO      EQU     107Q    ; " G CODE
ASCR    EQU     15Q     ; " CR CODE
ASBS    EQU     10Q     ; " BS CODE
ASTB    EQU     11Q     ; " TAB CODE
ASSP    EQU     40Q     ; " SP CODE
ASPRD   EQU     56Q     ; " PRD CODE
ASCMA   EQU     54Q     ; " CMA CODE
DLC35   EQU     7500Q   ;35 MSEC DELAY COUNT
DC500   EQU     16Q     ;500 MSEC MULTIPLIER
CTPIN:  PUSH    PSW     ;SAVE A & FLAGS, START INITL
        MVI     A,177Q  ;ENABLE ACCESS TO
        OUT     CTPCN   ;CTYPE DATA REG
        OUT     CTPDA   ;ALL CTYPE BITS HI
        XRA     A       ;ENABLE ACCESS TO
        OUT     CTPCN   ;CTYPE & PORT B
        OUT     PBCN    ;DATA DIR REG
        OUT     PBDA    ;PORT B TO BE INPUT
        MVI     A,177Q  ;PA0 - PA6 TO BE OUTPUTS &
        OUT     CTPDA   ;PA7 TO BE INPUT
        OUT     CTPCN   ;ENABLE ACCESS TO CTYPE &
        OUT     PBCN    ;PORT B DATA REGS
CTPIN1: IN      CTPDA   ;CTYPE READY?
        RAL
        JC      CTPIN1  ;NO, TRY AGAIN
        MVI     A,UNLOK ;YES, PUT CTYPE
        OUT     CTPDA   ;IN L.C.
        CALL    DEL35   ;WAIT 35 MSEC
```

```
        MVI     A,NULL    ;OUTPUT NULL TO
        OUT     CTPDA     ;CTYPE DATA REG
        POP     PSW       ;RESTORE A & FLAGS &
        RET               ;BACK TO CALLER
CNVRT:  PUSH    H         ;SAVE HL
        PUSH    B         ;SAVE BC
        PUSH    PSW       ;SAVE A & FLAGS
        CPI     40Q       ;ASCII  40Q?
        JC      AUX       ;YES, CHK AUX FUNCTIONS
        CPI     140Q      ;NO. ASCII  140Q?
        JC      SPCHK     ;YES, CONTINUE
        POP     PSW       ;NO. INVALID -
        POP     B         ;RESTORE A, FLAGS,
        POP     H         ;BC & HL &
        RET               ;RETURN TO CALLER
SPCHK:  CPI     ASSP      ;ASCII SPACE?
        JNZ     PRDCHK    ;NO, CHK PERIOD
        MVI     A,SPC     ;YES, SPACE TOAA &
        JMP     CHR2A1    ;DO IT
PRDCHK: CPI     ASPRD     ;ASCII PERIOD?
        JNZ     CMACHK    ;NO, CHK COMMA
        MVI     A,PRD     ;YES, PERIOD TO A &
        JMP     CHR2A1    ;TYPE IT
CMACHK: CPI     ASCMA     ;ASCII COMMA?
        JNZ     CNVRT1    ;NO, CONTINUE
        MVI     A,COM     ;YES, COMMA TO A &
        JMP     CHR2A1    ;TYPE IT
CNVRT1: SUI     40Q       ;MAKE ASCII 0-63 DECIMAL
        MOV     C,A       ;MODIFIED
        MVI     B,0       ;ASCII TO BC
        LXI     H,TABLE   ;TABLE START TO HL
        DAD     B         ;POINT TO ENTRY
        MOV     A,M       ;CTYPE CODE TO A
        MOV     B,A       ;SAVE IT IN B
        ANI     200Q      ;U.C. REQ'D?
        JNZ     UCCHK     ;YES, CHK CTYPE
        IN      PBDA      ;NO, CTYPE IN L.C.?
        RAR
        JNC     CHR2A     ;YES, CHAR TO A & TYPE
        MVI     A,UNLOK   ;NO, UNLOCK
        CALL    TYPE      ;CTYPE SHIFT
        JMP     CHR2A     ;NOW CHAR TO A & TYPE
UCCHK:  IN      PBDA      ;CTYPE IN U.C.?
        RAR
        JC      CHR2A     ;YES, CHAR TO A & TYPE
XX:     IN      CTPDA
        RAL
        JC      XX
        CALL    DEL35
        MVI     A,LOCK
        OUT     CTPDA
```

```
        MVI     C,12Q
XXX:    CALL    DEL35
        DCR     C
        JNZ     XXX
        MVI     A,NULL
        OUT     CTPDA
CHR2A:  MOV     A,B         ;CTYPE CODE TO A
CHR2A1: CALL    TYPE        ;TYPE IT
BACK:   POP     PSW         :RESTORE A,
        POP     B           ;FLAGS, BC, &
        POP     H           ;HL & BACK
        RET                 ;TO CALLER
AUX:    CPI     ASCR        ;ASCII CR?
        JNZ     AUX1        ;NO, CHK OTHERS
        MVI     A,CR        ;YES, CTYPE CR
        JMP     CHR2A1      ;CODE TO A & DO IT
AUX1:   CPI     ASBS        ;ASCII BS?
        JNZ     AUX2        ;NO CHK OTHERS
        MVI     A,BS        ;YES, CTYPE BS
        JMP     CHR2A1      ;TO A & DO IT
AUX2:   CPI     ASTB        ;ASCII TAB?
        JNZ     BACK        ;NO. INVALID - RETURN
        MVI     A,TB        ;YES, CTYPE TAB
        JMP     CHR2A1      ;CODE TO A & DO IT
TYPE:   PUSH    H           ;SAVE HL
        PUSH    B           ;SAVE BC
        PUSH    PSW         ;SAVE A & FLAGS
        MOV     B,A         ;SAVE CTYPE CODE IN B
TYPE1:  IN      CTPDA       ;CTYPE READY?
        RAL
        JC      TYPE1       ;NO, TRY AGAIN
        CALL    DEL35
        MOV     A,B         ;YES, MOVE CTYPE CODE
        OUT     CTPDA       ;TO A & TYPE IT
        CALL    DEL35       ;WAIT 35 MSEC
        MVI     A,NULL      ;NULL CHAR
        OUT     CTPDA       ;TO CTYPE
        MOV     A,B         ;IF CODE IS
        CPI     CR          ;FOR CR
        JZ      DL500       ;BS OR TAB,
        CPI     BS          ;WAIT
        JZ      DL500       ;FOR 500 MSEC
        CPI     TB          ;BEFORE
        JZ      DL500       ;RESTORING A,
TYPE2:  POP     PSW         ;FLAGS, BC &
        POP     B           ; & RETURNING
        POP     H           ;TO THE
        RET                 ;CALLER
DEL35:  PUSH    B           ;SAVE BC
        PUSH    PSW         ;SAVE A & FLAGS
        XRA     A           ;CLEAR A TO 0
```

```
        LXI     B,DLC35  ;35 MSEC DELAY COUNT TO B
DEL351: DCX     B
        CMP     B        ;DONE?
        JNZ     DEL351   ;NO, LOOP
        POP     PSW      ;YES, RESTORE A,
        POP     B        ;FLAGS & BC &
        RET              ;RETURN TO CALLER
DL500:  MVI     C,DC500  ;500 MSEC MULTIPLIER TO C
DL5001: CALL    DEL35    ;WAIT 35 MSEC
        DCR     C        ;DONE?
        JNZ     DL5001   ;NO, LOOP
        JMP     TYPE2    ;YES, JUMP BACK & RETURN
TABLE:  DB      154Q,340Q,264Q,300Q,260Q,240Q,200Q,064Q
        DB      302Q,262Q,322Q,324Q,044Q,104Q,066Q,024Q
        DB      062Q,140Q,120Q,100Q,060Q,040Q,020Q,000Q
        DB      122Q,102Q,242Q,042Q,177Q,124Q,177Q,224Q
        DB      320Q,274Q,250Q,252Q,272Q,334Q,330Q,230Q
        DB      312Q,214Q,326Q,306Q,232Q,212Q,234Q,254Q
        DB      310Q,246Q,352Q,332Q,314Q,350Q,346Q,210Q
        DB      206Q,270Q,226Q,177Q,177Q,177Q,177Q,304Q
START:  LXI     B,40Q
        LXI     H,STACK
        DAD     B
        SPHL
        CALL    CTPIN
        MVI     B,0
        LXI     H,FIRST
        LXI     D,LAST
DOIT:   MOV     A,M
        CALL    CNVRT
        IN      STAT
        RAR
        JNC     HERE
        IN      TERM
ESCCHK: CPI     ESC
        JNZ     STPCHK
        JMP     MON
STPCHK: CPI     STP
        JNZ     HERE
        MVI     B,1
HERE:   MOV     A,B
        ANA     A
        JZ      HERE1
        MOV     A,M
        CPI     ASCR
        JNZ     HERE1
        CALL    WAIT
HERE1:  MOV     A,H
        CMP     D
        JNZ     HERE2
        MOV     A,L
        CMP     E
```

```
          JNZ     HERE2
          JMP     MON
HERE2:    INX     H
          JMP     DOIT
WAIT:     MVI     B,ASCR
          CALL    TRMOUT
          MVI     B,"W"
          CALL    TRMOUT
          MVI     B,"A"
          CALL    TRMOUT
          MVI     B,"I"
          CALL    TRMOUT
          MVI     B,"T"
          CALL    TRMOUT
          MVI     B,15Q
          CALL    TRMOUT
          MVI     B,12Q
          CALL    TRMOUT
          MVI     B,0
WAIT1:    IN      STAT
          RAR
          JNC     WAIT1
          IN      TERM
          CPI     ESC
          JNZ     PRTCHK
          JMP     MON
PRTCHK:   CPI     GO
          JNZ     WAIT1
          RET
TRMOUT:   IN      STAT
          RAR,RAR
          JNC     TRMOUT
          MOV     A,B
          OUT     TERM
          RET
STACK:    DS      40Q
          BEG     START
          END     PRT
```

PRT - CYBERTYPE PRINT ROUTINE

```
2800  F5 3E 7F D3 40 D3 41 AF    2808  D3 40 D3 42 D3 43 3E 7F
2810  D3 41 D3 40 D3 42 DB 41    2818  17 DA 16 28 3E 62 D3 41
2820  CD E7 28 3E 7F D3 41 F1    2828  C9 E5 C5 F5 FE 20 DA 9E
2830  28 FE 60 DA 3A 28 F1 C1    2838  E1 C9 FE 20 C2 44 28 3E
2840  6C C3 97 28 FE 2E C2 4E    2848  28 3E 36 C3 97 28 FE 2C
2850  C2 58 28 3E 24 C3 97 28    2858  D6 20 4F 06 00 21 01 29
2860  09 7E 47 E6 80 C2 76 28    2868  DB 43 1F D2 96 28 3E 62
2870  CD BC 28 C3 96 28 DB 43    2878  1F DA 96 28 DB 41 17 DA
2880  7C 28 CD E7 28 3E 02 D3    2888  41 0E 0A CD E7 28 0D C2
2890  8B 28 3E 7F D3 41 78 CD    2898  BC 28 F1 C1 E1 C9 FE 0D
28A0  C2 A8 28 3E 12 C3 97 28    28A8  FE 08 C2 B2 28 3E 64 C3
28B0  97 28 FE 09 C2 9A 28 3E    28B8  04 C3 97 28 E5 C5 F5 47
28C0  DB 41 17 DA C0 28 CD E7    28C8  28 78 D3 41 CD E7 28 3E
28D0  7F D3 41 78 FE 12 CA F5    28D8  28 FE 64 CA F5 28 FE 04
28E0  CA F5 28 F1 C1 E1 C9 C5    28E8  F5 AF 01 40 0F 0B B8 C2
28F0  ED 28 F1 C1 C9 0E 0E CD    28F8  E7 28 0D C2 F7 28 C3 E3
2900  28 6C E0 B4 C0 B0 A0 80    2908  34 C2 B2 D2 D4 24 44 36
2910  14 32 60 50 40 30 20 10    2918  00 52 42 A2 22 7F 54 7F
2920  94 D0 BC A8 AA BA DC D8    2928  98 CA 8C D6 C6 9A 8A 9C
2930  AC C8 A6 EA DA CC E8 E6    2938  88 86 B8 96 7F 7F 7F 7F
2940  C4 01 20 00 21 D4 29 09    2948  F9 CD 00 28 06 00 21 00
2950  2C 11 FF 3F 7E CD 29 28    2958  DB 10 1F D2 6F 29 DB 11
2960  FE 1B C2 68 29 C3 40 00    2968  FE 53 C2 6F 29 06 01 78
2970  A7 CA 7D 29 7E FE 0D C2    2978  7D 29 CD 8E 29 7C BA C2
2980  8A 29 7D BB C2 8A 29 C3    2988  40 00 23 C3 54 29 06 0D
2990  CD C9 29 06 57 CD C9 29    2998  06 41 CD C9 29 06 49 CD
29A0  C9 29 06 54 CD C9 29 06    29A8  0D CD C9 29 06 0A CD C9
29B0  29 06 00 DB 10 1F D2 B3    29B8  29 DB 11 FE 1B C2 C3 29
29C0  C3 40 00 FE 47 C2 B3 29    29C8  C9 DB 10 1F 1F D2 C9 29
29D0  78 D3 11 C9 F3 F0 35 30    29D8  F5 75 D7 55 F3 F7 92 CC
29E0  34 CC CF 28 93 CC 34 CC    29E8  35 29 9A 28 87 54 20 00
29F0  0A 2C 58 29
```

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```
;PRT
;FIRST ADDR @ 25414Q
;LAST  ADDR @ 25417Q
;
          ORG       24000Q
FIRST     EQU       26000Q
LAST      EQU       37777Q
STAT      EQU       20Q       ;TERM STAT REG
TERM      EQU       21Q       ;TERM DATA REG
CTPCN     EQU       100Q      ;CTYPE CONT REG
CTPDA     EQU       101Q      ;CTYPE DATA/DDR REGS
PBCN      EQU       102Q      ;PORT B CONT REG
PBDA      EQU       103Q      ;PORT B DATA/DDR REGS
CR        EQU       22Q       ;CTYPE CR CODE
BS        EQU       144Q      ; " BS CODE
TB        EQU       4         ; " TAB CODE
SPC       EQU       154Q      ; " SP CODE
PRD       EQU       66Q       ; " PRD CODE
COM       EQU       44Q       ; " CMA CODE
NULL      EQU       177Q      ; " NULL CODE
LOCK      EQU       2         ; " SHFT LK CODE
UNLOK     EQU       142Q      ; " SHFT UNLK CODE
ESC       EQU       33Q       ;ASCII ESC CODE
STP       EQU       123Q      ; " S CODE
GO        EQU       107Q      ; " G CODE
ASCR      EQU       15Q       ; " CR CODE
ASBS      EQU       10Q       ; " BS CODE
ASTB      EQU       11Q       ; " TAB CODE
ASSP      EQU       40Q       ; " SP CODE
ASPRD     EQU       56Q       ; " PRD CODE
ASCMA     EQU       54Q       ; " CMA CODE
DLC35     EQU       7500Q     ;35 MSEC DELAY COUNT
DC500     EQU       16Q       ;500 MSEC MULTIPLIER
CTPIN:    PUSH      PSW       ;SAVE A & FLAGS, START INITL
          MVI       A,177Q    ;ENABLE ACCESS TO
          OUT       CTPCN     ;CTYPE DATA REG
          OUT       CTPDA     ;ALL CTYPE BITS HI
          XRA       A         ;ENABLE ACCESS TO
          OUT       CTPCN     ;CTYPE & PORT B
          OUT       PBCN      ;DATA DIR REG
          OUT       PBDA      ;PORT B TO BE INPUT
          MVI       A,177Q    ;PA0 - PA6 TO BE OUTPUTS &
          OUT       CTPDA     ;PA7 TO BE INPUT
          OUT       CTPCN     ;ENABLE ACCESS TO CTYPE &
          OUT       PBCN      ;PORT B DATA REGS
CTPIN1:   IN        CTPDA     ;CTYPE READY?
          RAL
          JC        CTPIN1    ;NO, TRY AGAIN
          MVI       A,UNLOK   ;YES, PUT CTYPE
          OUT       CTPDA     ;IN L.C.
          CALL      DEL35     ;WAIT 35 MSEC
```

```
        MVI     A,NULL    ;OUTPUT NULL TO
        OUT     CTPDA     ;CTYPE DATA REG
        POP     PSW       ;RESTORE A & FLAGS &
        RET               ;BACK TO CALLER
CNVRT:  PUSH    H         ;SAVE HL
        PUSH    B         ;SAVE BC
        PUSH    PSW       ;SAVE A & FLAGS
        CPI     40Q       ;ASCII  40Q?
        JC      AUX       ;YES, CHK AUX FUNCTIONS
        CPI     140Q      ;NO. ASCII  140Q?
        JC      SPCHK     ;YES, CONTINUE
        POP     PSW       ;NO. INVALID -
        POP     B         ;RESTORE A, FLAGS,
        POP     H         ;BC & HL &
        RET               ;RETURN TO CALLER
SPCHK:  CPI     ASSP      ;ASCII SPACE?
        JNZ     PRDCHK    ;NO, CHK PERIOD
        MVI     A,SPC     ;YES, SPACE TOAA &
        JMP     CHR2A1    ;DO IT
PRDCHK: CPI     ASPRD     ;ASCII PERIOD?
        JNZ     CMACHK    ;NO, CHK COMMA
        MVI     A,PRD     ;YES, PERIOD TO A &
        JMP     CHR2A1    ;TYPE IT
CMACHK: CPI     ASCMA     ;ASCII COMMA?
        JNZ     CNVRT1    ;NO, CONTINUE
        MVI     A,COM     ;YES, COMMA TO A &
        JMP     CHR2A1    ;TYPE IT
CNVRT1: SUI     40Q       ;MAKE ASCII 0-63 DECIMAL
        MOV     C,A       ;MODIFIED
        MVI     B,0       ;ASCII TO BC
        LXI     H,TABLE   ;TABLE START TO HL
        DAD     B         ;POINT TO ENTRY
        MOV     A,M       ;CTYPE CODE TO A
        MOV     B,A       ;SAVE IT IN B
        ANI     200Q      ;U.C. REQ'D?
        JNZ     UCCHK     ;YES, CHK CTYPE
        IN      PBDA      ;NO, CTYPE IN L.C.?
        RAR
        JNC     CHR2A     ;YES, CHAR TO A & TYPE
        MVI     A,UNLOK   ;NO, UNLOCK
        CALL    TYPE      ;CTYPE SHIFT
        JMP     CHR2A     ;NOW CHAR TO A & TYPE
UCCHK:  IN      PBDA      ;CTYPE IN U.C.?
        RAR
        JC      CHR2A     ;YES, CHAR TO A & TYPE
XX:     IN      CTPDA
        RAL
        JC      XX
        CALL    DEL35
        MVI     A,LOCK
        OUT     CTPDA
```

```
        MVI     C,12Q
XXX:    CALL    DEL35
        DCR     C
        JNZ     XXX
        MVI     A,NULL
        OUT     CTPDA
CHR2A:  MOV     A,B         ;CTYPE CODE TO A
CHR2A1: CALL    TYPE        ;TYPE IT
BACK:   POP     PSW         ;RESTORE A,
        POP     B           ;FLAGS, BC, &
        POP     H           ;HL & BACK
        RET                 ;TO CALLER
AUX:    CPI     ASCR        ;ASCII CR?
        JNZ     AUX1        ;NO, CHK OTHERS
        MVI     A,CR        ;YES, CTYPE CR
        JMP     CHR2A1      ;CODE TO A & DO IT
AUX1:   CPI     ASBS        ;ASCII BS?
        JNZ     AUX2        ;NO CHK OTHERS
        MVI     A,BS        ;YES, CTYPE BS
        JMP     CHR2A1      ;TO A & DO IT
AUX2:   CPI     ASTB        ;ASCII TAB?
        JNZ     BACK        ;NO. INVALID - RETURN
        MVI     A,TB        ;YES, CTYPE TAB
        JMP     CHR2A1      ;CODE TO A & DO IT
TYPE:   PUSH    H           ;SAVE HL
        PUSH    B           ;SAVE BC
        PUSH    PSW         ;SAVE A & FLAGS
        MOV     B,A         ;SAVE CTYPE CODE IN B
TYPE1:  IN      CTPDA       ;CTYPE READY?
        RAL
        JC      TYPE1       ;NO, TRY AGAIN
        CALL    DEL35
        MOV     A,B         ;YES, MOVE CTYPE CODE
        OUT     CTPDA       ;TO A & TYPE IT
        CALL    DEL35       ;WAIT 35 MSEC
        MVI     A,NULL      ;NULL CHAR
        OUT     CTPDA       ;TO CTYPE
        MOV     A,B         ;IF CODE IS
        CPI     CR          ;FOR CR
        JZ      DL500       ;BS OR TAB,
        CPI     BS          ;WAIT
        JZ      DL500       ;FOR 500 MSEC
        CPI     TB          ;BEFORE
        JZ      DL500       ;RESTORING A,
TYPE2:  POP     PSW         ;FLAGS, BC &
        POP     B           ;HL & RETURNING
        POP     H           ;TO THE
        RET                 ;CALLER
DEL35:  PUSH    B           ;SAVE BC
        PUSH    PSW         ;SAVE A & FLAGS
        XRA     A           ;CLEAR A TO 0
```

```
        LXI     B,DLC35  ;35 MSEC DELAY COUNT TO B
DEL351: DCX     B
        CMP     B        ;DONE?
        JNZ     DEL351   ;NO, LOOP
        POP     PSW      ;YES, RESTORE A,
        POP     B        ;FLAGS & BC &
        RET              ;RETURN TO CALLER
DL500:  MVI     C,DC500  ;500 MSEC MULTIPLIER TO C
DL5001: CALL    DEL35    ;WAIT 35 MSEC
        DCR     C        ;DONE?
        JNZ     DL5001   ;NO, LOOP
        JMP     TYPE2    ;YES, JUMP BACK & RETURN
TABLE:  DB      154Q,340Q,264Q,300Q,260Q,240Q,200Q,064Q
        DB      302Q,262Q,322Q,324Q,044Q,104Q,066Q,024Q
        DB      062Q,140Q,120Q,100Q,060Q,040Q,020Q,000Q
        DB      122Q,102Q,242Q,042Q,177Q,124Q,177Q,224Q
        DB      320Q,274Q,250Q,252Q,272Q,334Q,330Q,230Q
        DB      312Q,214Q,326Q,306Q,232Q,212Q,234Q,254Q
        DB      310Q,246Q,352Q,332Q,314Q,350Q,346Q,210Q
        DB      206Q,270Q,226Q,177Q,177Q,177Q,177Q,304Q
START:  LXI     B,40Q
        LXI     H,STACK
        DAD     B
        SPHL
        CALL    CTPIN
        MVI     B,0
        LXI     H,FIRST
        LXI     D,LAST
DOIT:   MOV     A,M
        CALL    CNVRT
        IN      STAT
        RAR
        JNC     HERE
        IN      TERM
ESCCHK: CPI     ESC
        JNZ     STPCHK
        JMP     MON
STPCHK: CPI     STP
        JNZ     HERE
        MVI     B,1
HERE:   MOV     A,B
        ANA     A
        JZ      HERE1
        MOV     A,M
        CPI     ASCR
        JNZ     HERE1
        CALL    WAIT
HERE1:  MOV     A,H
        CMP     D
        JNZ     HERE2
        MOV     A,L
        CMP     E
```

```
        JNZ     HERE2
        JMP     MON
HERE2:  INX     H
        JMP     DOIT
WAIT:   MVI     B,ASCR
        CALL    TRMOUT
        MVI     B,"W"
        CALL    TRMOUT
        MVI     B,"A"
        CALL    TRMOUT
        MVI     B,"I"
        CALL    TRMOUT
        MVI     B,"T"
        CALL    TRMOUT
        MVI     B,15Q
        CALL    TRMOUT
        MVI     B,12Q
        CALL    TRMOUT
        MVI     B,0
WAIT1:  IN      STAT
        RAR
        JNC     WAIT1
        IN      TERM
        CPI     ESC
        JNZ     PRTCHK
        JMP     MON
PRTCHK: CPI     GO
        JNZ     WAIT1
        RET
TRMOUT: IN      STAT
        RAR,RAR
        JNC     TRMOUT
        MOV     A,B
        OUT     TERM
        RET
STACK:  DS      40Q
        BEG     START
        END     PRT
```

PRT - CYBERTYPE PRINT ROUTINE

```
2800  F5 3E 7F D3 40 D3 41 AF    2808  D3 40 D3 42 D3 43 3E 7F
2810  D3 41 D3 40 D3 42 DB 41    2818  17 DA 16 28 3E 62 D3 41
2820  CD E7 28 3E 7F D3 41 F1    2828  C9 E5 C5 F5 FE 20 DA 9E
2830  28 FE 60 DA 3A 28 F1 C1    2838  E1 C9 FE 20 C2 44 28 3E
2840  6C C3 97 28 FE 2E C2 4E    2848  28 3E 36 C3 97 28 FE 2C
2850  C2 58 28 3E 24 C3 97 28    2858  D6 20 4F 06 00 21 01 29
2860  09 7E 47 E6 80 C2 76 28    2868  DB 43 1F D2 96 28 3E 62
2870  CD BC 28 C3 96 28 DB 43    2878  1F DA 96 28 DB 41 17 DA
2880  7C 28 CD E7 28 3E 02 D3    2888  41 0E 0A CD E7 28 0D C2
2890  8B 28 3E 7F D3 41 78 CD    2898  BC 28 F1 C1 E1 C9 FE 0D
28A0  C2 A8 28 3E 12 C3 97 28    28A8  FE 08 C2 B2 28 3E 64 C3
28B0  97 28 FE 09 C2 9A 28 3E    28B8  04 C3 97 28 E5 C5 F5 47
28C0  DB 41 17 DA C0 28 CD E7    28C8  28 78 D3 41 CD E7 28 3E
28D0  7F D3 41 78 FE 12 CA F5    28D8  28 FE 64 CA F5 28 FE 04
28E0  CA F5 28 F1 C1 E1 C9 C5    28E8  F5 AF 01 40 0F 0B B8 C2
28F0  ED 28 F1 C1 C9 0E 0E CD    28F8  E7 28 0D C2 F7 28 C3 E3
2900  28 6C E0 B4 C0 B0 A0 80    2908  34 C2 B2 D2 D4 24 44 36
2910  14 32 60 50 40 30 20 10    2918  00 52 42 A2 22 7F 54 7F
2920  94 D0 BC A8 AA BA DC D8    2928  98 CA 8C D6 C6 9A 8A 9C
2930  AC C8 A6 EA DA CC E8 E6    2938  88 86 B8 96 7F 7F 7F 7F
2940  C4 01 20 00 21 D4 29 09    2948  F9 CD 00 28 06 00 21 00
2950  2C 11 FF 3F 7E CD 29 28    2958  DB 10 1F D2 6F 29 DB 11
2960  FE 1B C2 68 29 C3 40 00    2968  FE 53 C2 6F 29 06 01 78
2970  A7 CA 7D 29 7E FE 0D C2    2978  7D 29 CD 8E 29 7C BA C2
2980  8A 29 7D BB C2 8A 29 C3    2988  40 00 23 C3 54 29 06 0D
2990  CD C9 29 06 57 CD C9 29    2998  06 41 CD C9 29 06 49 CD
29A0  C9 29 06 54 CD C9 29 06    29A8  0D CD C9 29 06 0A CD C9
29B0  29 06 00 DB 10 1F D2 B3    29B8  29 DB 11 FE 1B C2 C3 29
29C0  C3 40 00 FE 47 C2 B3 29    29C8  C9 DB 10 1F 1F D2 C9 29
29D0  78 D3 11 C9 F3 F0 35 30    29D8  F5 75 D7 55 F3 F7 92 CC
29E0  34 CC CF 28 93 CC 34 CC    29E8  35 29 9A 28 87 54 20 00
29F0  0A 2C 58 29
```

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